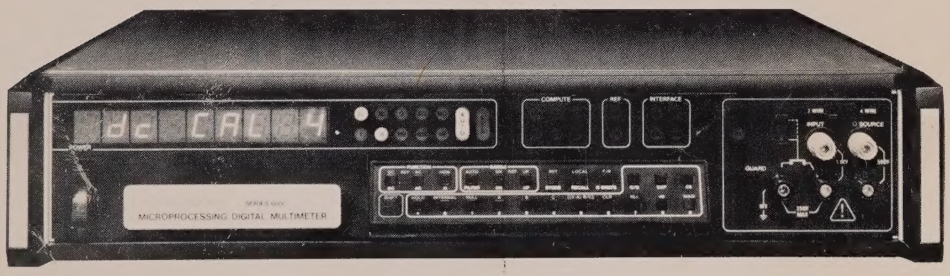
AMPLITUDE MEASUREMENT SYSTEM

OPERATORS MANUAL

6000

MICROPROCESSING DIGITAL MULTIMETER



RACAL-DANA Instruments Inc.

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PUBLICATION NO. 980513

OPTIONS:
035H HIGH SPEED S/H
10 TRUE RMS
41 10mV RANGE

OPERATORS MANUAL

6000

MICROPROCESSING DIGITAL MULTIMETER

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FOR YOUR SAFETY

Before undertaking any maintenance procedure, whether it be a specific troubleshooting or maintenance procedure described herein or an exploratory procedure aimed at determining whether there has been a malfunction, read the applicable section of this manual and note carefully the WARNING and CAUTION notices contained therein.

The equipment described in this manual contains voltage hazardous to human life and safety and which is capable of inflicting personal injury. The cautionary and warning notes are included in this manual to alert operator and maintenance personnel to the electrical hazards and thus prevent personal injury and damage to equipment.

If this instrument is to be powered from the AC Mains through an autotransformer (such as a Variac or equivalent) ensure that the common connector is connected to the neutral (earthed pole) of the power supply.

Before operating the unit ensure that the protective conductor (green wire) is connected to the ground (earth) protective conductor of the power outlet. Do not defeat the protective feature of the third protective conductor in the power cord by using a two conductor extension cord or a three-prong/two-prong adapter.

Maintenance and calibration procedures contained in this manual sometimes call for operation of the unit with power applied and protective covers removed. Read the procedures carefully and heed Warnings to avoid "live" circuit points to ensure your personal safety.

Before operating this instrument.

1. Ensure that the instrument is configured to operate on the voltage available at the power source. See Installation section.
2. Ensure that the proper fuse is in place in the instrument for the power source on which the instrument is to be operated.
3. Ensure that all other devices connected to or in proximity to this instrument are properly grounded or connected to the protective third-wire earth ground.

If at any time the instrument:

- Fails to operate satisfactorily
- Shows visible damage
- Has been stored under unfavorable conditions
- Has sustained stress

It should not be used until the performance has been checked by qualified personnel.

FOR YOUR SAFETY

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SECTION 1 GENERAL DESCRIPTION

1.1 INTRODUCTION.

1.1.1 This manual contains the operating instructions for the Racal-Dana Model 6000 Microprocessing Digital Multimeter. This section of the manual contains a base description of the operating features of the instrument along with the technical specifications. Section 2 of this manual contains unpacking and installation instructions along with details necessary for system connection. Section 3 contains the operating instructions. These operating instructions include illustrations and the description of all controls, connectors and indicators on the front and rear panels of the instrument. Also included is a description of the operating characteristics and step by step operating instructions for each mode and feature of the instrument. A calibration check is also included in Section 3 for the convenience of operating personnel who desire to verify that the instrument is operating properly and that it is operating within its specifications.

1.1.2 The instrument is designed to operate with the IEEE-488-1975 General Purpose Interface Bus. The device dependent messages for operating the Model 6000 DMM in the remote mode are also included in Section 3 along with addressing instructions and a description of the system communication format and sequence.

1.1.3 Section 4 contains the laboratory calibration procedure. The laboratory calibration routine is designed to prompt the operator and the laboratory cal procedure provided in Section 4 is designed to operate step by step with pre-programmed Digical™ digital calibration sequence built into the instrument.

1.2 DESCRIPTION.

1.2.1 The Racal-Dana Model 6000 Microprocessing Digital Multimeter is a 6 1/2 digit "delayed dual sloped" instrument capable of measuring DC volts on 6 ranges, AC volts on 4 ranges and resistance on 9 ranges. The instrument will automatically select the correct range if operated in the autorange mode or a specific range may be selected manually by the operator. It is equipped with a selectable input filter which may be used to reduce possible error when making measurements in an electrical noise environment.

1.2.2 It is equipped to make resistance measurements conveniently in the 2-wire resistance mode. It may be selected simply by setting a front panel switch to the 2-wire mode position. If the accuracy of a 4-wire resistance measurement is required, the front panel switch is set to the 4-wire position and the unknown resistance is connected to the ohms source terminals on the front of the instrument and to the input terminals by separate lead pairs.

1.2.3 The input terminals of the measurement circuits are floating but the low side of the input terminals may be easily connected to guard through use of a front panel switch.

1.2.4 Bench operation is controlled by the operator through use of a front panel keyboard. For a system operation the instrument is connected through a standard GPIB interface connector on the rear panel.

1.2.5 In addition to voltage and resistance measurements the instrument is capable of measuring the ratio between voltages connected to the front panel input terminals and input terminals located on the rear panel. If the optional AC converter is used the instrument will calculate AC/DC, DC/AC, and AC/AC ratios. The instrument is not restricted to a single range, e.g., the 10 volt range for ratio measurements; the operator can select any range for making ratio measurements. The DMM is also capable of measuring the ratio between a resistance and AC or DC voltage (with the voltage source used as the reference). With the True RMS AC converter and ohms option more than 70 combinations of ratio functions and ranges can be commanded from the keyboard or over the IEEE 488 interface.

1.3 SPECIFICATIONS.

1.3.1 The specifications are given in Table 1.1

Table 1.1 - Specifications

DC VOLTS (Included In Basic Instrument)	
Ranges:	± 100 mV, ± 1.00000, ± 10.0000 ± 100.000, ± 1000.00V
Resolution:	0.001% Range on 5 1/2 Digit Mode 0.0001% Range on 6 1/2 Digit Mode
Overrange:	60% except 1000V Range. 1100V on 1000V Range.
Maximum Input Voltage:	1100V DC or 1500V Peak AC All Ranges
Accuracy:	(5 1/2 digit mode, after Auto-Cal, following two hour warm-up).
24 Hours, 23°C ± 1°C	
10V Range	± 1 Digit
1,100,1000V Ranges	± (.001% Input + 1 Digit)
100mV Ranges	± (.002% Input + 5 Digits)
90 Days, 23°C ± 5°C	
10V Range	± (.001% Input + 1 Digit)
1,100,1000V Ranges	± (.002% Input + 1 Digit)
100mV Range	± (.003% Input + 5 Digits)
1 Year, 23°C ± 5°C	
10V Range	± (.003% Input + 1 Digit)
1,100,1000V Ranges	± (.004% Input + 1 Digit)
100mV Range	± (.005% Input + 5 Digits)
Temperature Coefficient:	(0°C to 50°C, 5 1/2 digit mode, after Auto-Cal, after temperature change)
10V Range	± (1.5 ppm + .05 Digit)/°C
1,100,1000V Range	± (3 ppm + .1 Digit)/°C
100mV Range	± (4 ppm + .5 Digit)/°C
Non-Linearity: 23°C + 5°/C	All Ranges ≤ 0.5 Digit to 160% F.S. in 5 1/2 Digit Mode

DC VOLTS continued	
Input Impedances:	100 mV, 1V, 10V Ranges: > 10,000MΩ 100V, 1KV Ranges: 10MΩ
Input Bias Current:	≤ 30 pA at 23°C
Input Bias Current TC:	Doubles Every 10°C
Normal Mode Rejection:	
Unfiltered	48 dB at Multiples of 60 Hz
Filtered	100 dB at 60 Hz
Settling Time:	
Unfiltered	Analog output settles to within 0.01% of final value in 5 msec with 10K source; 10 msec on 100V range.
Filtered	Analog output settles to within 0.01% of final value in 450 msec with 10K source on all ranges.
Common Mode Rejection:	
With 100Ω Unbalance in either Lead	
Unfiltered	140 dB DC 120 dB at 61 Hz and Below Plus an Additional 54 dB at Harmonics of 60 Hz
Filtered	140 dB DC to 61 Hz 126 dB 61 Hz to 100 KHz

DC MILLIVOLTS (Option 41)	
Ranges:	± 10 mV
Resolution:	5 1/2 Digit Mode: 100 Nano Volts 6 1/2 Digit Mode: 100 Nano Volts
Overrange:	120% (Reads 22 mV input with no degradation of accuracy)
Maximum Input Voltage:	350V DC or 250V RMS
Input Impedance:	100 MΩ minimum shunted by 4.8 KΩ in series with 1.5 μF
Input Bias Current:	300 pA Typical at 23°C
Normal Mode Rejection:	Same as DC Function
Common Mode Rejection:	Same as DC Function

Table 1.1 - Specifications (continued)

DC MILLIVOLTS continued	
Settling Time, Unfiltered:	Analog output settles to within .01% of final value in 850 msec with up to 10KΩ source resistance
Accuracy:	(5 1/2 digit mode, after Auto-Cal, following two hour warm-up. With source resistance ≤ 1KΩ and input zeroed by pushing NULL with shorted input leads.)
24 Hours, 23°C ± 1°C	
10mV Range	±(.005% Input + 5 Digits)
90 Days, 23°C ± 5°C	
10mV Range	±(.008% Input + 5 Digits)
1 Year, 23°C ± 5°C	
10mV Range	±(.01% Input + 5 Digits)
Temperature Coefficient:	(0°C to 50°C, 5 1/2 digit mode, after Auto-Cal, after temperature change. With source resistance ≤ 1KΩ and input zeroed by pushing NULL with shorted input leads.)
10mV Range	±(.002% Input + .5 Digit)/°C

OHMS (Option 24)	
Ranges:	1.00000Ω with Option 41 10.0000Ω, 100.000Ω, 1.00000KΩ, 10.0000KΩ, 100.000KΩ, 1.00000MΩ, 10.0000MΩ, 100.000MΩ.
Resolution:	0.001% F.S. in all Ranges 5 1/2 Digit Mode 0.0001% F.S. in all Ranges 6 1/2 Digit Mode
Overrange:	60% on all Ranges
Maximum Input Voltage:	+ 350V Peak on 1Ω Range ± 500V Peak on 10Ω–100MΩ
Measurement Scheme:	Modified 4-Wire

OHMS continued	
Accuracy:	(5 1/2 digit mode, after Auto-Cal, following two hour warm-up
24 Hours, 23°C ± 1°C	
1Ω Range	±(.015% Input + 20 Digits)
10Ω Range	±(.003% Input + 5 Digits)
100Ω - 1MΩ Ranges	±(.002% Input + 1 Digit)
10MΩ Range	±(.01% Input + 1 Digit)
100MΩ Range	±(.02% Input + 1 Digit)
90 Days, 23°C ± 5°C	
1Ω Range	±(.02% Input + 20 Digits)
10Ω Range	±(.005% Input + 5 Digits)
100Ω - 1MΩ Ranges	±(.003% Input + 1 Digit)
10MΩ Range	±(.03% Input + 1 Digit)
100MΩ Range	±(.03% Input + 1 Digit)
1 Year, 23°C ± 5°C	
1Ω Range	±(.03% Input + 20 Digits)
10Ω Range	±(.006% Input + 5 Digits)
100Ω - 1MΩ Ranges	±(.004% Input + 1 Digit)
10MΩ Range	±(.04% Input + 1 Digit)
100MΩ Range	±(.04% Input + 1 Digit)
Temperature Coefficient:	(0°C to 50°C, 5 1/2 digit mode, after Auto-Cal, after temperature change.)
1Ω Range	±(.002% Input + 2 Digits)/°C
10Ω Range	±(.0008% Input + .5 Digit)/°C
100Ω - 1MΩ Ranges	±(.0007% Input + .1 Digit)/°C
10MΩ Range	±(.003% Input + .1 Digit)/°C
100MΩ Range	±(.005% Input + .1 Digit)/°C
Open Circuit Voltage:	1Ω Range: 24V Max 10Ω to 1KΩ Range: 8V Max 10KΩ to 100MΩ Range: 24V Max
Current Through Unknown:	1Ω, 10Ω, 100Ω Ranges: 10 mA 1KΩ, 10KΩ Ranges: 1 mA 100KΩ Range: 100μA 1MΩ Range: 10μA 10MΩ Range: 1μA 100MΩ Range: 100 nA
Normal Mode Rejection:	
Unfiltered	48 dB at Multiples of 60 Hz
Filtered	100 dB at 60 Hz

Table 1.1 - Specifications (continued)

OHMS continued	
Settling Time: To Rated Accuracy	1Ω Range: 1 Second 10Ω to 10MΩ Ranges: 30 mSec 100MΩ Range: 300 mSec
Ohms Guard:	Use "Analog Out" Low on Rear Panel when in Ohms

ANALOG SIGNAL OUTPUT	
General Description:	Input scaled and buffered. DC voltage is available for driving a recorder
Output Impedance:	Less than 0.5Ω
Current Available:	1 mA maximum. Protected if output is shorted
Over-Voltage:	Output clamped with diodes (no current limit) to ± 24V
Settling Time:	Same as Function selected

HARDWARE RATIO (OPTIONS 11 & 34)	
Signal Input:	Any voltage range front or rear input terminals as selected
Reference Input:	Rear reference input terminals
DC REFERENCE (OPTION 34)	
Readout:	Signal Input ÷ Ref Input Ratios are displayed in scientific notation.
Signal Ranges:	Same as Selected Function
Reference Polarity:	Positive Only
Signal Polarity:	Bipolar
Reference Voltage Range:	+1V to +10.5V
Reference Common Mode Voltage Range:	Voltage between + Ref In and Sig In less than ± 15V
Maximum Signal Voltage:	Same as Selected Function

HARDWARE RATIO continued	
DC REFERENCE continued	
Reference Input Impedance: Both leads with respect to -Sig In	$10^9\Omega$ minimum (+ Lead) $3.3 \times 10^7\Omega \pm 10\%$ (– Lead)
Reference Input Bias Current: Either Lead	Less than 7 nA
Reference Settling Time:	Settles to .01% of final value in 50 msec
Accuracy: After Auto Cal with reference voltage applied	DC/DC Ratio Same as DC Accuracy (see Section 4) with error multiplied by $\left[\frac{10V}{REF\ V}\right] \times 2$ AC/DC Ratio Same as AC Accuracy with error multiplied by $\left[\frac{10V}{REF\ V}\right] \times 2$
Noise	(Noise of function) x $\frac{10V}{Ref\ V}$
AC REFERENCE (OPTION 11)	
Readout:	Signal input ÷ reference input Ratios are displayed in scientific notation.
Reference Ranges:	1V, 10V, 100V, 1000V RMS
Signal Ranges:	Same as Selected Function
Maximum Reference Voltage:	1000V RMS or 1500V Peak
Maximum Signal Voltage:	Same as Selected Function
Reference Voltage Range:	10% of F.S. to 160% F.S. except 1000V Range which is 10% to 100% of F.S.
Reference Input Impedance:	Same as AC Option 10
Ratio Accuracy: (Up to 10 KHz)	(Accuracy of Function) + (Accuracy of Option 10) The sum multiplied by $\frac{Reference\ Range}{Reference\ Input}$
Frequency Range:	20 Hz to 10 KHz
Reference Temperature Coefficient: (0°C to 50°C) After Auto-Cal	+ (0.004% RDG + 0.005% F.S.)/°C

Table 1.1 - Specifications (continued)

AC VOLTS TRUE RMS (Option 10)	
Ranges:	1.00000V, 10.0000V RMS 100.000V, 1000.00V RMS
Resolution:	0.001% of Range
Maximum Input Voltage:	1000V RMS or 1500V Peak, decreasing to 50V RMS at 300 KHz. $(1.5 \times 10^7$ V)(Hz) max. any Range.
Settling Time:	Settles to within 0.1% of Range:
Zero to F.S.	
"Filter" Out	80 mSec
"Filter" In	350 mSec
F.S. to 10% F.S.	Settles to within 0.1% Range:
"Filter" Out	100 mSec
"Filter" In	400 mSec
Input Impedance:	1MΩ in series with .22 μF, shunted by less than 200 pF to common. In DC coupled mode the .22 μF capacitor is shorted.
Common Mode Rejection: (100Ω Unbalance either lead. DC to 60 Hz)	Range / CMRR 1V / 120 dB 10V / 100 dB 100V / 80 dB 1000V / 60 dB
Accuracy:	(After Auto-Cal, following two hour warm-up, sinewave input.) Vin ≤ 500V 0.1% F.S. < Vin ≤ 160% F.S. For Vin > 500V, add 0.1% of RDG to specification.
24 Hours, 23°C ± 1°C	
20 Hz - 30 Hz (Filt.)	±(.5% Input + 50 Digits)
30 Hz - 50 Hz (Filt.)	±(.2% Input + 50 Digits)
50 Hz - 100 Hz (Filt.)	±(.1% Input + 50 Digits)
100 Hz - 20 KHz (Filt.)	±(.06% Input + 50 Digits)
200 Hz - 20 KHz (Unfilt.)	±(.06% Input + 50 Digits)
20 KHz - 50 KHz (Both)	±(.09% Input + 100 Digits)
50 KHz - 100 KHz (Both)	±(.38% Input + 180 Digits)
100 KHz - 300 KHz (Both) (10V, 100V, 1000V Ranges)	±(3% Input + 500 Digits)
100 KHz - 300 KHz (Both) (1V Range)	±(5% Input + 1000 Digits)
For full accuracy above 150 VAC the FILTER should be selected.	

AC VOLTS continued	
90 Days, 23°C ± 5°C	
20 Hz - 30 Hz (Filt.)	±(.5% Input + 60 Digits)
30 Hz - 50 Hz (Filt.)	±(.21% Input + 60 Digits)
50 Hz - 100 Hz (Filt.)	±(.11% Input + 60 Digits)
100 Hz - 20 KHz (Filt.)	±(.07% Input + 60 Digits)
200 Hz - 20 KHz (Unfilt.)	±(.07% Input + 60 Digits)
20 KHz - 50 KHz (Both)	±(.1% Input + 100 Digits)
50 KHz - 100 KHz (Both)	±(.4% Input + 200 Digits)
100 KHz - 300 KHz (Both) (10V, 100V, 1000V Ranges)	±(3% Input + 500 Digits)
100 KHz - 300 KHz (Both) (1V Range)	±(5% Input + 1000 Digits)
For full accuracy above 150 VAC the FILTER should be selected.	
6 Months, 23°C ± 5°C	
20 Hz - 30 Hz (Filt.)	±(.52% Input + 70 Digits)
30 Hz - 50 Hz (Filt.)	±(.22% Input + 70 Digits)
50 Hz - 100 Hz (Filt.)	±(.12% Input + 70 Digits)
100 Hz - 20 KHz (Filt.)	±(.08% Input + 70 Digits)
200 Hz - 20 KHz (Unfilt.)	±(.08% Input + 70 Digits)
20 KHz - 50 KHz (Both)	±(.11% Input + 110 Digits)
50 KHz - 100 KHz (Both)	±(.42% Input + 220 Digits)
100 KHz - 300 KHz (Both) (10V, 100V, 1000V Ranges)	±(4% Input + 600 Digits)
100 KHz - 300 KHz (Both) (1V Range)	±(6% Input + 1100 Digits)
For full accuracy above 150 VAC the FILTER should be selected.	
Temperature Coefficient:	± (0.004% RDG + 0.005% F.S.)/°C
Crest Factor:	7:1 at full scale $7 \times \sqrt{\frac{F.S.}{V_{IN}}}$ for other voltages

Table 1.1 - Specifications (continued)

AC VOLTS AVERAGING (Option 14)	
Ranges:	1.00000V, 10.0000V, 100.000V, 1000.00V
Resolution:	.001% of Range
Maximum Input Voltage:	1000V RMS or 1500V Peak, decreasing to 20V RMS at 1 MHz. $(2x10^7 V)(Hz)$ max any Range.
Settling Time:	Settles to within rated accuracy of range:
Zero to F.S.	
"Filter" Out	200 msec
"Filter" In	600 msec
F.S. to 10% F.S.	
"Filter" Out	200 msec
"Filter" In	600 msec
Input Impedance:	1MΩ in series with .22μF, shunted by less than 100 pF to common.
Common Mode Rejection:	Range / CMRR
100Ω Unbalance either lead. DC to 60 Hz	1V 120 dB 10V 100 dB 100V 80 dB 1000V 60 dB
Accuracy:	(After Auto-Cal, following two hour warm-up, sinewave input.) Vin ≤ 500V 0.1% F.S. < Vin ≤ 160% F.S. For Vin ≥ 500V, add 0.1% of RDG to specification for f ≤ 5 KHz; add 0.2% of RDG for f > 5 KHz.
24 Hours, 23°C ± 1°C	
20 Hz - 30 Hz (Filt.)	±(.3% Input + 2 Digits)
30 Hz - 50 Hz (Filt.)	±(.2% Input + 2 Digits)
50 Hz - 100 Hz (Filt.)	±(0.05% Input + 2 Digits)
100 Hz - 5 KHz (Filt.)	±(.03% Input + 2 Digits)
300 Hz - 5 KHz (Unfilt.)	±(.03% Input + 2 Digits)
5 KHz - 50 KHz (Both)	±(.04% Input + 5 Digits)
50 KHz - 100 KHz (Both)	±(.05% Input + 10 Digits)
100 KHz - 300 KHz (Both)	±(.6% Input + 20 Digits)
300 KHz - 1 MHz (Both)	±(2.5% Input + 70 Digits)

AC VOLTS continued	
90 Days, 23°C ± 5°C	
20 Hz - 30 Hz (Filt.)	±(.31% Input + 4 Digits)
30 Hz - 50 Hz (Filt.)	±(.21% Input + 4 Digits)
50 Hz - 100 Hz (Filt.)	±(.06% Input + 4 Digits)
100 Hz - 5 KHz (Filt.)	±(.04% Input + 4 Digits)
300 Hz - 5 KHz (Unfilt.)	±(.04% Input + 4 Digits)
5 KHz - 50 KHz (Both)	±(.05% Input + 7 Digits)
50 KHz - 100 KHz (Both)	±(.06% Input + 12 Digits)
100 KHz - 300 KHz (Both)	±(.61% Input + 22 Digits)
300 KHz - 1 MHz (Both)	±(2.5% Input + 72 Digits)
6 Months, 23°C ± 5°C	
20 Hz - 30 Hz (Filt.)	±(.32% Input + 5 Digits)
30 Hz - 50 Hz (Filt.)	±(.22% Input + 5 Digits)
50 Hz - 100 Hz (Filt.)	±(.07% Input + 5 Digits)
100 Hz - 5 KHz (Filt.)	±(.05% Input + 5 Digits)
300 Hz - 5 KHz (Unfilt.)	±(.05% Input + 5 Digits)
5 KHz - 50 KHz (Both)	±(.06% Input + 8 Digits)
50 KHz - 100 KHz (Both)	±(.07% Input + 13 Digits)
100 KHz - 300 KHz (Both)	±(.62% Input + 23 Digits)
300 KHz - 1 MHz (Both)	±(2.5% Input + 73 Digits)
Temperature Coefficient:	(0°C to 50°C, after Auto-Cal, after temperature change).
50 Hz - 20 KHz (Filt.)	±(.003% Input + .5 Digit)
20 KHz - 100 KHz (Both)	±(.005% Input + 2 Digits)
100 KHz - 1 MHz (Both)	±(.02% Input + 10 Digits)

Table 1.1 - Specifications (continued)

FAST A/D (OPTIONS 03 & 03SH) GENERAL INFORMATION (NORMAL DVM INPUT TERMINALS)	
Optional A/D converter which allows conversion at up to 34,000 readings/sec.	
Function:	Any function except millivolts (opt. 41) or 1 ohm.
Ranges:	Same as Function Selected
Maximum Input:	Same as Function Selected
Settling Time:	Same as Function Selected
Accuracy:	24 hr., 23°C ± 1°C Same as function selected
0V to ± Full Scale	± .05% Rdg ± 1.5 counts
± Full Scale to 160% Full Scale	± .05% Rdg ± 3 counts
	1 yr., 23°C ± 5°C Same as function selected
0V to ± Full Scale	± .5% Rdg ± 4 counts
± Full Scale to 160% Full Scale	± .5% Rdg ± 6 counts
Temperature Coefficient:	Same as Function Selected ± .015% Rdg ± .1 count/°C
All Functions except mV and 1 Ohm range	Add ± .01% Rdg to above for Ohms Function
Read Rate:	
With display	250 reading/sec
Without display (GPIB output)	6000 reading/sec
With external trigger pulse (negative going TTL pulse 200 ns to 20 μs in duration. Must be bounce free)	34,000 reading/sec (Does not include settling time.)
Output Format:	12 bit, two's complement
Data Scale Factor:	
Signal Directly to Fast A/D Pins 24, 25 (03SH only)	10 mV/count ± 20.47 volts produces octal data display of ± 3777
Signal Taken From Isolator Output (03 and 03SH)	Linear up to 160% of selected range. Isolator output of ± 16.00 volts produces octal data display of ± 3067
1000V Range	1V/count
100V Range	100 mV/count
10V Range	10 mV/count
1V Range	1 mV/count
100 mV Range	100 μV/count

SAMPLE & HOLD FAST A/D (OPTION 03 SH) ADDITIONAL INFORMATION	
Delay (Variable):	2 to 20 μsec.
Delay Offset: (External Trigger to Delay Out)	
No Delay Selected	100ns ± 30ns
Repeatability	± 2ns
Offset:	
Delay Out to Signal Hold (For total delay add offset to delay or delay offset)	140ns ± 20ns
Repeatability	± 3ns
03SH INPUT CONNECTOR SPECIFICATIONS (PINS 24, 25)	
Input Voltage Range	± 10 Volts DC
Max. Measureable Input:	± 20 Volts
Maximum Input Without Damage:	100 Volts DC or Peak AC
Accuracy:	24 hr., 23°C ± 1°C
0V to ± 10V	± .05% ± 1.5 counts
−10V to −20V and +10V to +20V	± .05% ± 3 counts
	1 yr., 23°C ± 5°C
0V to ± 10V	± .5% ± 4 counts
−10V to −20V and +10V to +20V	± .5 ± 6 counts
Temperature Coefficient:	± .015% Rdg ± .1 count/°C
Input Resistance:	> 100KΩ
Bandwidth (3 dB):	1 MHz
Settling Time: 20V Step, 1KΩ Source	6 μs to 30 mV 2 μs to 200 mV

Table 1.1 - Specifications (continued)

GENERAL	
Display:	5 full decades plus overrange digit
Overrange:	60% overrange with full accuracy on all ranges and functions except: AC (1000 VAC RMS maximum) DC (1100 volts maximum) 10 mV (120% overrange) 1Ω (120% overrange)
Overrange Indication:	Display reads "OL" except in 10mV range. DMM automatically upranges when 10 mV range is overloaded.
Warm-up Time To 24 Hr. Specifications:	2 hours
Warm-up Time To Fully Stabilize To 6 Month Specifications:	1 hour
Maximum Common Mode Voltage:	1000V DC or peak AC, Guard to case with interface common tied to case. 250V, analog common to guard.
Front Panel Input Terminals:	+ signal input + I (+ Ω current output) – I (– Ω current return) – IN (– signal common) guard
Rear Panel Terminals:	+ EXT REF input EXT REF Common + INPUT (+ signal input) + I (+ Ω current output) – INPUT (– signal common) guard – I (– Ω current return) Analog Output Analog Common Ext Trigger
Ranging:	Autorange standard Uprange at 160% range (nominal) Downrange at 15% range (nominal) Manual range standard
Range of Mathematical Constants:	± 1 E-9 to ± 9999.99E9

GENERAL continued	
Power Requirements:	100, 120, 220, or 240V ± 10% 75 watts maximum 60 Hz Standard
Weight:	25 lbs. (net)
Dimensions: (See Figure 1.1)	3.5" Height x 18" Deep x 16.75" Wide
Rack Mounting:	Standard corporate package
Temperature Range:	Operating 0°C to 50°C Storage –40°C to +70°C at 80% RH
Humidity, Operating:	< 75% RH; 25°C to 40°C < 50% RH; 40°C to 50°C
Vibration - Operating:	0.025" Double amplitude to 55 Hz for 15 minutes

SYSTEMS (BCD, OPTION 59)	
Data Output Information:	All BCD outputs of display, 4-Bit Range code function flags, polarity flags, special flags, and logic supplies
Logic Type:	Low power Schottky TTL levels, 8-4-2-1 BCD
Maximum Read Rate:	13 per sec. to full scale, 33 per sec. to full scale in Superfast, 60 Hz Operation
Isolation:	Data output common may be floated up to 200V peak from power line common
Remote Programming Input Information:	Provides isolated programming of all DMM functions and ranges
Functions:	Function lines are programmed by a closure to ground (low TTL level)
Ranges:	Range lines are 8-4-2-1 coded positive true logic

Table 1.1 - Specifications (continued)

REMOTE PROGRAMMING (Option 55 GPIB)	
Output Information:	Numeric data, polarity, function, range, and special flags.
Input Information:	Functions, ranges, microprocessing functions. (Full control of all instrument capabilities.)
Buss Compatibility:	IEEE STD-488-1975

IEEE STD-488-1975 Subset Capability

Subset	Function	Capability
SH1	Source Handshake	Complete
AH1	Acceptor Handshake	Complete
T5	Talker	Complete
TE0	Extended Talker	None
L4	Listener	All except listen only
LE0	Extended Listener	None
SR1	Service Request	Complete
RL1	Remote/Local	Complete
PP0	Parallel Poll	None
DC1	Device Clear	Complete
DT1	Device Trigger	Complete
C0	Controller	None
E1	Open collector bus drivers	–

6 1/2 DIGIT MODE	
Ranges & Functions:	All ranges and functions same
Selection:	May be selected via front panel keyboard or programming
Display:	6 digit display with % overrange as noted for 5 1/2 digit operation
Accuracy:	Same as 5 1/2 digit

4 1/2 DIGIT MODE	
Fast integration mode, 1-2/3 msec. (60 Hz) conversion maximum (not including internal 15 msec reset)	
Ranges & Functions:	All ranges and functions same
Selection:	May be selected via front panel keyboard or programming
Display:	Four digit display with % over-range as noted for 5 1/2 digit operation
Accuracy:	Standard accuracy for range and function plus .03% of reading plus .03% of F.S.

READ RATES		
	With Display	Without Display
6 1/2 Digit	2 readings/sec	same
5 1/2 Digit	17 readings/sec	same
4 1/2 Digit	45 readings/sec	50 readings/sec
3 1/2 Digit (Fast A/D)	250 readings/sec	6000 readings/sec

Table 1.1 - Specifications (continued)

AUTOMATIC SOFTWARE RATIO $\frac{V1}{V2}$	
Signal Input (V1):	Front input terminals*
Reference Input (V2):	Rear input terminals*
Normal Mode Rejection:	Same as for function selected for both signal (V1) and reference (V2) inputs
Isolation:	1000 megohms between any front input terminal and any rear input terminal. Max 1000V DC or 1500 peak AC from any front input terminal to any rear input terminal.
*Inputs may be reversed using front/rear input programming by keyboard and remotely	
Signal Ranges: Reference Ranges:	Same as selected function 1, 10, 100, 1000V DC 1, 10, 100, 1000 V AC
Accuracy - DC/DC: Same Reference & Signal Range: 1-1000V Range: 100mV Range:	 $\pm$ .001% Rdg $\pm$ (.001% F.S. $\frac{RR}{RI}$)* $\pm$ .001% Rdg $\pm$ (.005% F.S. $\frac{RR}{RI}$)*
Different Signal & Reference Range: 1-1000V Range: 100mV Range:	 $\pm$ .002% Rdg $\pm$ (.002% F.S. $\frac{RR}{RI}$)* $\pm$ .007% Rdg $\pm$ (.01% F.S. $\frac{RR}{RI}$)*
Accuracy - AC/AC: Same Reference & Signal Range & Frequency: 100 Hz - 20 KHz 50 Hz - 50 KHz	 + .06% Input $\pm$ (.05% FS $\frac{RR}{RI}$)* $\pm$ .1% Input $\pm$ (.1% FS $\frac{RR}{RI}$)*
Accuracy - Mixed Functions:	Signal function specification and reference function specification (with % of range multiplied by $\frac{RR}{RI}$)*
Speed:	Approximately 1 second per reading + timeouts for signal/reference functions and ranges (Max timeout approx 500 mS)

*RR = Ref. Range
RI = Ref. Input

$\frac{RR}{RI} \geq 1$

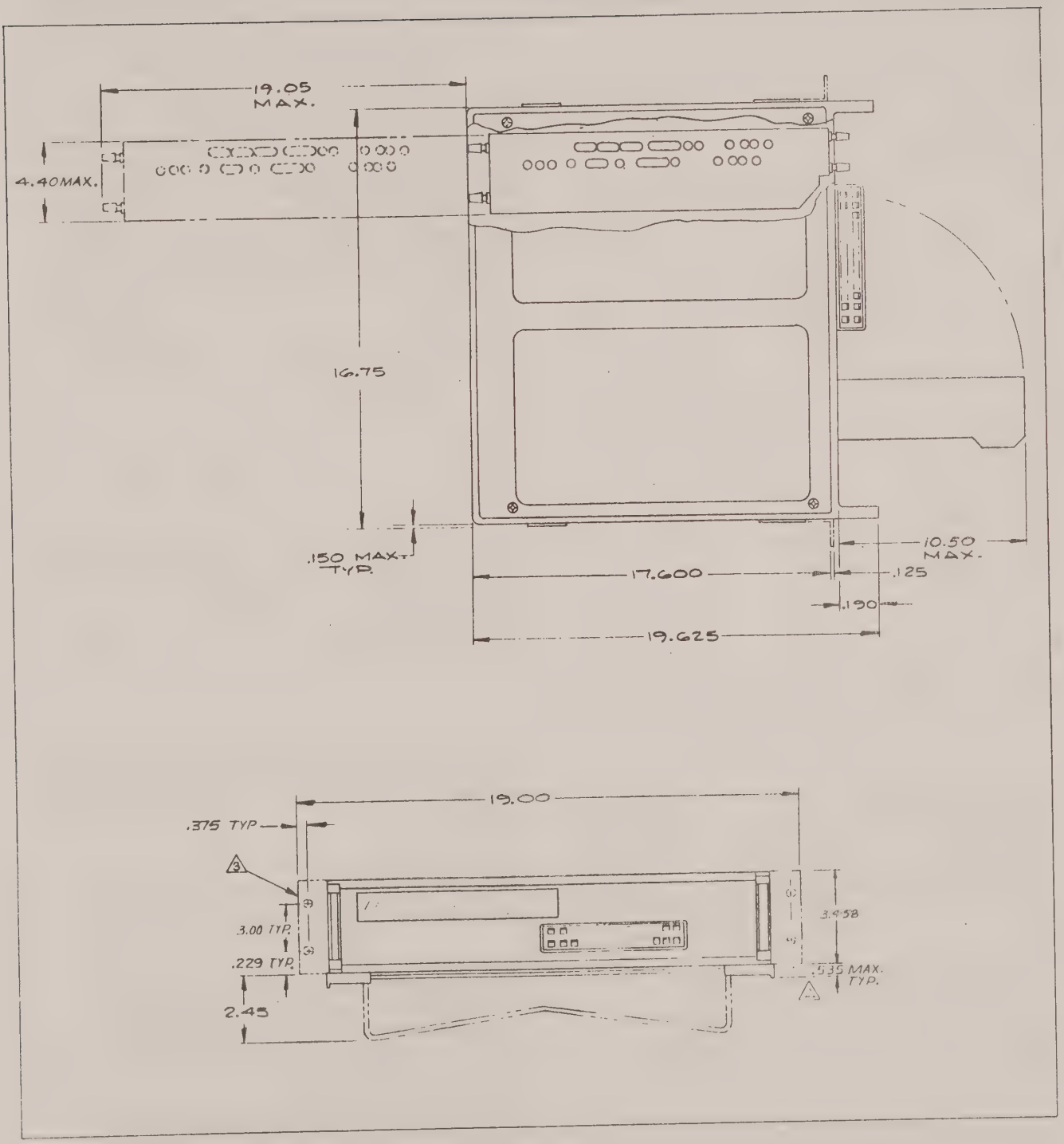


Figure 1.1 - Dimensional Outline

2.1 UNPACKING AND INSPECTION.

2.1.1 The Model 6000 DMM is packed in a molded plastic-foam form within a cardboard carton for shipment. The plastic form holds the DMM securely in the carton and absorbs any reasonable external shock normally encountered in transit. Prior to unpacking, examine the exterior of the shipping carton for any signs of damage. Carefully remove the DMM from the carton and inspect the exterior of the instrument for any signs of damage. If damage is found, notify the carrier immediately.

2.1.2 Included with the instrument in the packing container are the instruction manual and power cord.

2.2 BENCH OPERATION.

2.2.1 Each Model 6000 is equipped with a tilt bail or "kickstand" to enable the front of the instrument to be elevated for convenient bench use. The tilt bail is attached to the two front supporting "feet" at the bottom of the instrument. For use, the bail is pulled down to its supporting position.

2.3 RACK MOUNTING.

2.3.1 The instrument can be mounted in a standard 19-inch rack with the optional rack-mounting flanges (403402, includes attaching hardware). To install the flanges, proceed as follows:

a. With instrument on its side, remove four Phillips-head screws holding bottom cover. Remove cover. Remove screws holding feet (and bail) in place. Replace bottom cover.

b. Place one of the supplied screws through each of the two holes in the mounting flange (figure 2.1). Thread a securing nut onto each screw just enough to attach it to the screw (approximately one turn).

c. Place the mounting flange onto the mounting slot in the instrument side panel so that the securing nuts fit entirely into the slot. Be sure the rack-mount slots on the flange are toward the front of the instrument.

d. Tighten screws. The securing nuts will rotate and hold the flange securely in place.

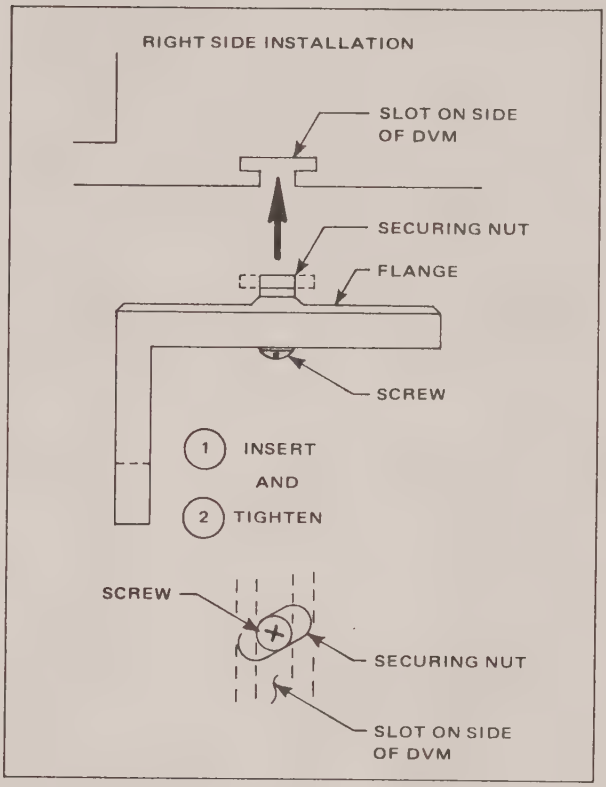


Figure 2.1 - Rack Mount Installation

2.4 POWER CONNECTIONS.

2.4.1 Standard units operate on either 100, 115, 230 or 240 volts, 60 Hz (50 or 400 Hz available). Power consumption is less than 75 watts. Operation on either of the four line voltages is selectable by placement of a small printed circuit card in the combination voltage selector/fuse holder/power cord connector assembly. Selection of a specific line voltage is accomplished as follows:

a. Disconnect the AC power cord from the power connector (reference (9) , Figure 3.3, Table 3.3) and slide the plastic fuse cover to the left so that it covers the power cord connector pins. This exposes the fuse and the safety interconnect device.

b. Pull the small lever marked FUSE PULL and swing it to the left. This removes the fuse from the fuse holder and makes the voltage selector card accessible for removal.

c. Remove the voltage selector PCB and reinsert it so that the desired operating line voltage is visible.

d. Swing the lever marked FUSE PULL back to the right and snap it into the closed position.

e. Replace the fuse and slide the plastic window to the right so that it covers the voltage selector PCB and fuse.

f. Plug the AC line cord into the line cord connector. The instrument is now ready for operation.

2.4.2 A standard power cable having a three-pin plug is supplied with the instrument. It connects to POWER connector J203. The ground pin is attached to the instrument case. It is important that this pin be connected to a good quality earth ground.

2.4.3 Fuse receptacle F201 on the rear panel is equipped with a .75 amp fuse.

2.5 INPUT/OUTPUT CABLING.

2.5.1 Binding Posts.

2.5.1.1 Several connectors on the Model 6000 consist of a pair of binding posts spaced so as to accept standard "banana" plugs. The connectors are:

Front Panel	Rear Panel
± INPUT	± EXT REF
± OHMS CURRENT	± INPUT
GUARD	± 4-WIRE Ω
	GUARD
BNC CONNECTORS	EXT TRIG
	ANALOG OUTPUT

2.5.1.2 Input cables to fit the above connectors can be ordered from Racal-Dana. The Part Numbers are shown below:

CABLE ASSEMBLY	PART NUMBER
AC POWER	403530
INPUT 4-WIRE Ω SOURCE EXTERNAL REFERENCE	406168

2.5.2 Fast A/D Output Connector (Options 03 and 03SH).

2.5.2.1 When Option 03 or 03SH is installed the instrument is equipped with a rear panel connector for system connection of the fast analog-to-digital output. The pin-signal assignments for these connectors are illustrated in Figures 2.2 and 2.3. The instrument is supplied with the mating connector.

2.5.3 Interface Bus Connector (Option 55).

2.5.3.1 When Option 55 is installed the instrument is equipped with a General Purpose Interface Bus connector for connection to a system. The pin-signal assignments for this connector are illustrated in Figure 2.4. This connector is configured to conform to the IEEE-488-1975 Standard Interface Specification.

2.5.4 Parallel BCD Output/Program Connector (Option 59).

When the instrument is configured for remote control and parallel BCD output, data is routed out to the system through the rear panel connectors illustrated in Figures 2.5 and 2.6. This illustration shows the pin signal assignments for the parallel BCD program input connector and parallel BCD output connector.

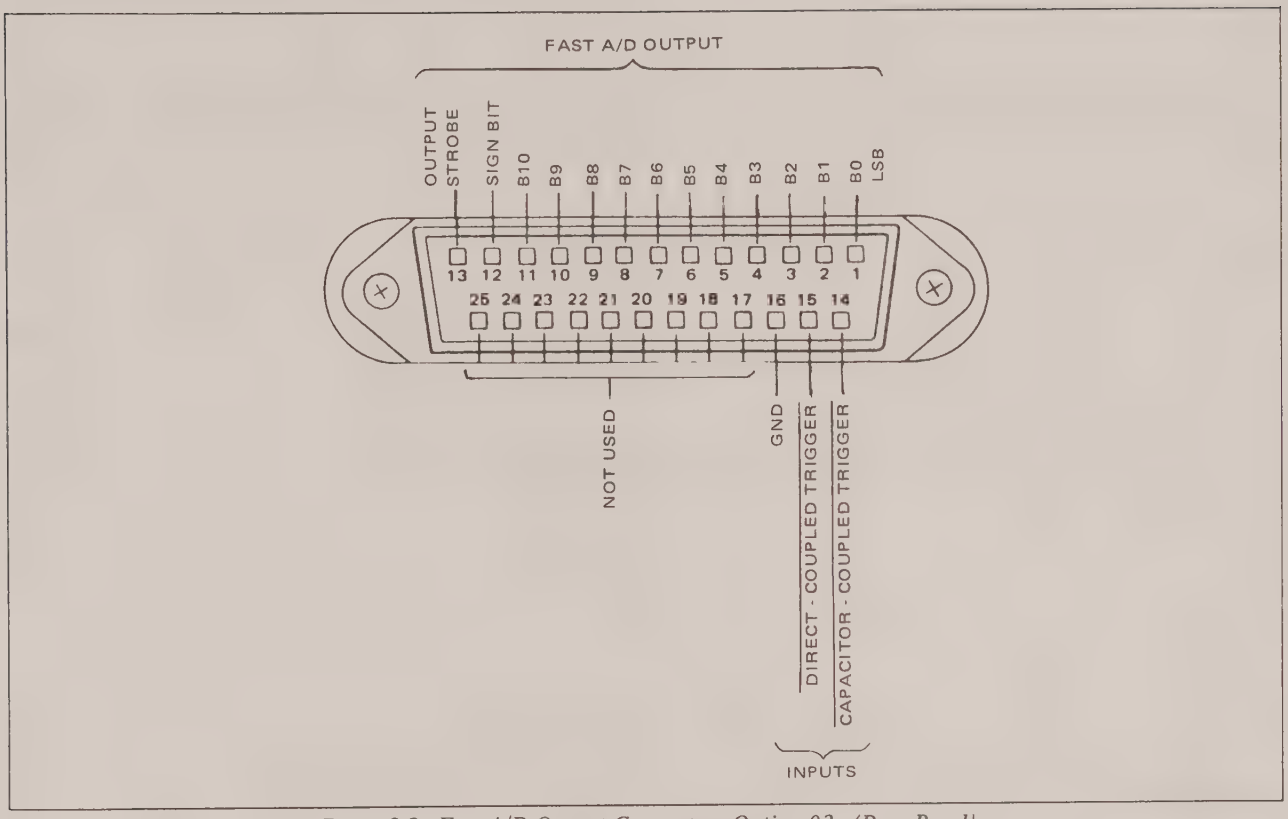


Figure 2.2 - Fast A/D Output Connector - Option 03 (Rear Panel)

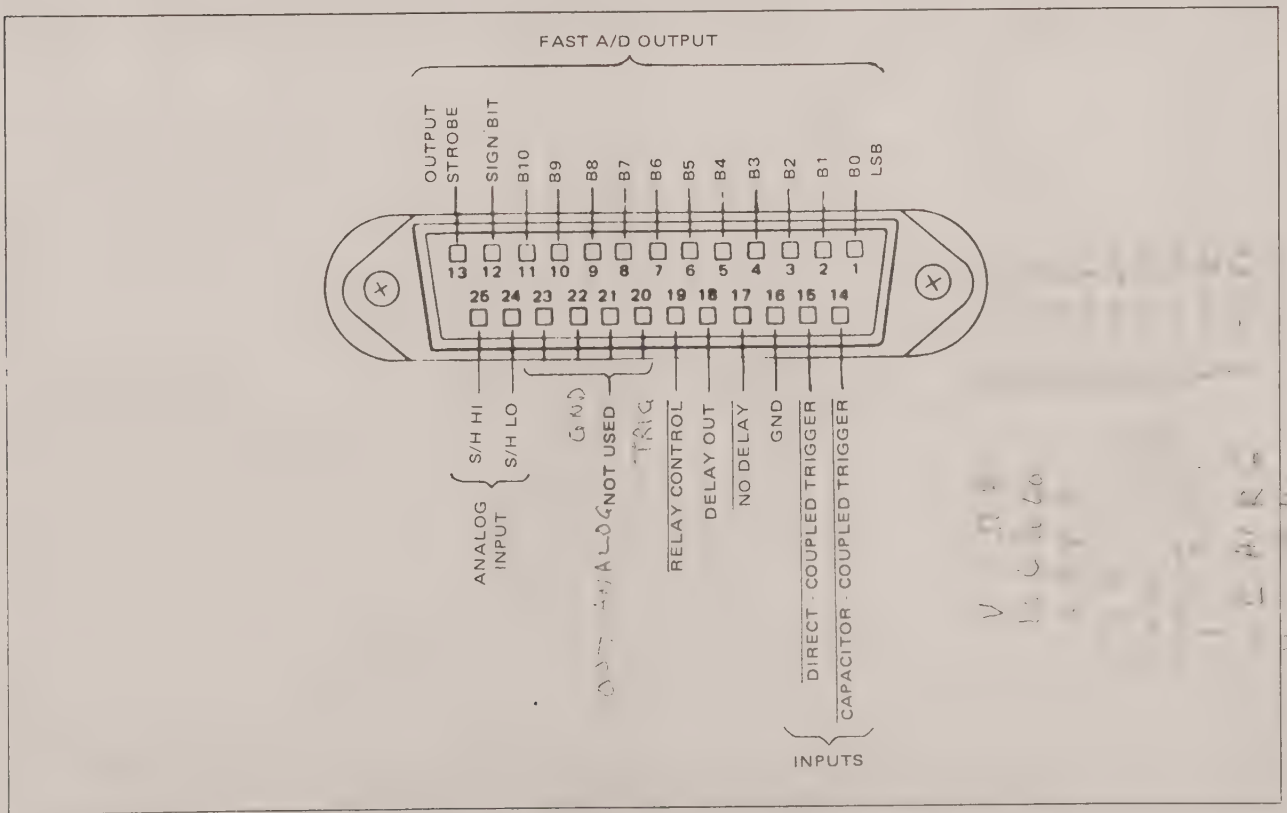


Figure 2.3 - Sample & Hold Fast A/D Output Connector - Option 03SH (Rear Panel)

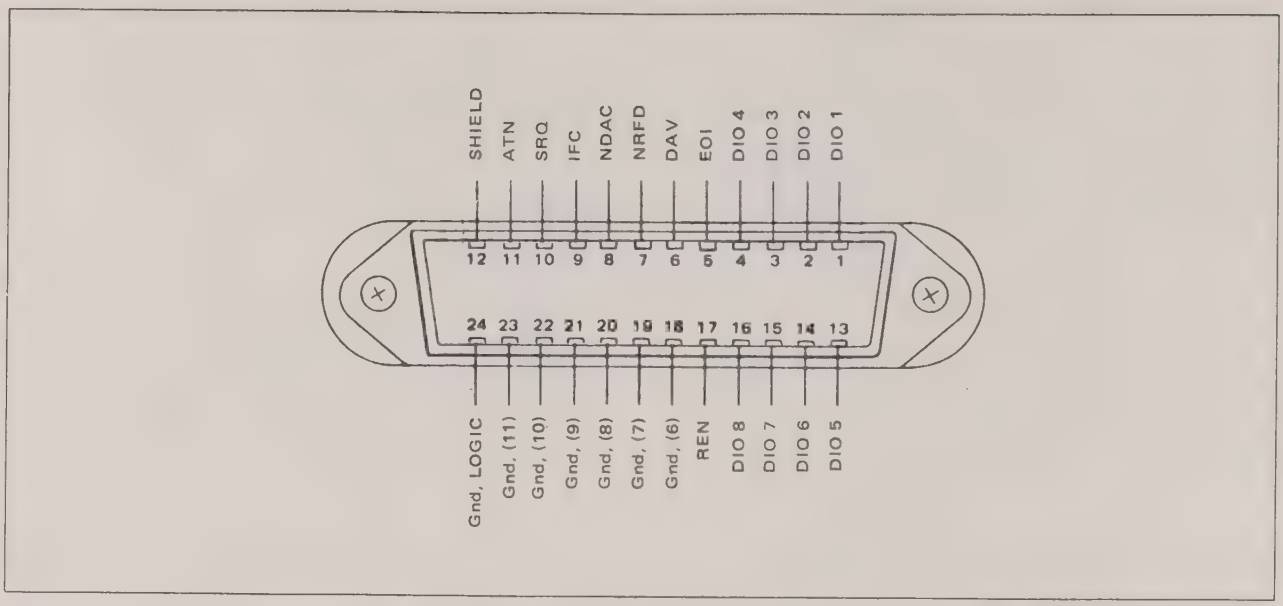


Figure 2.4 - GPIB Connector (Rear Panel)

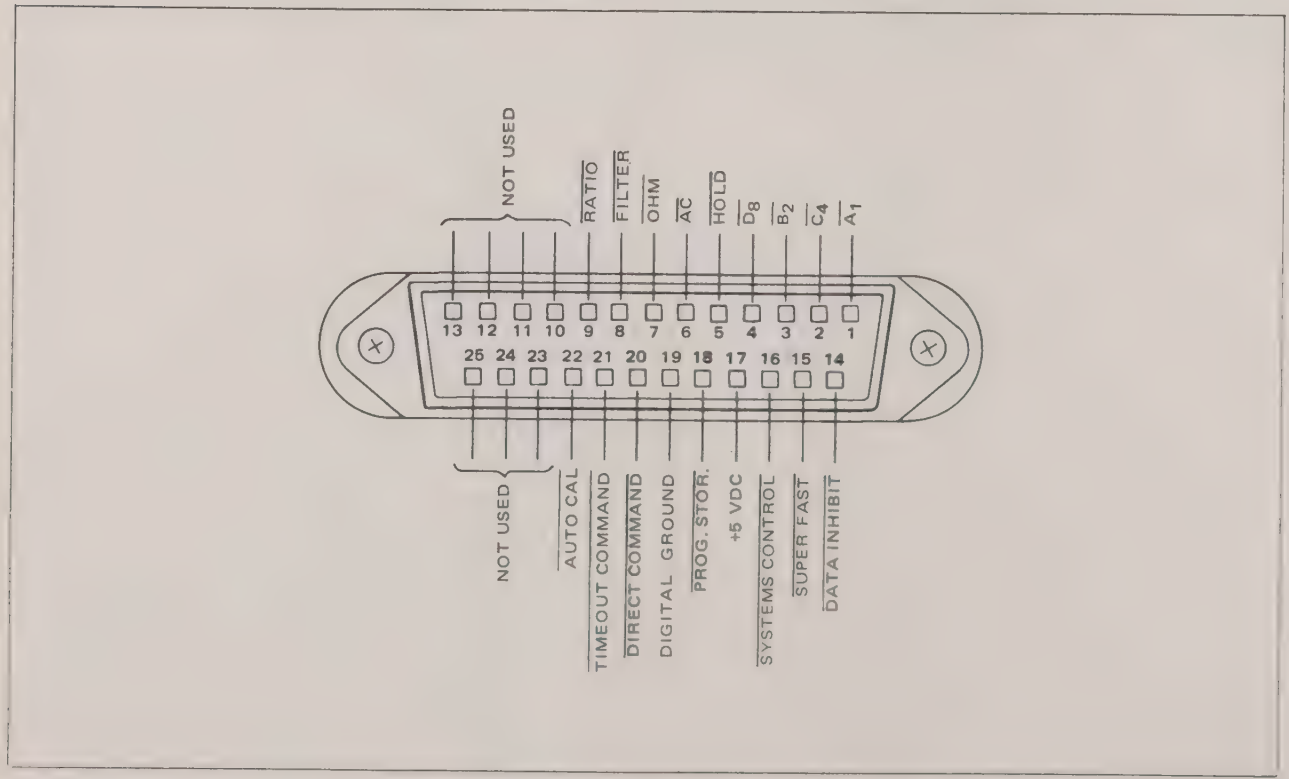


Figure 2.5 - J209 Parallel BCD Program Input Connector (Rear Panel)

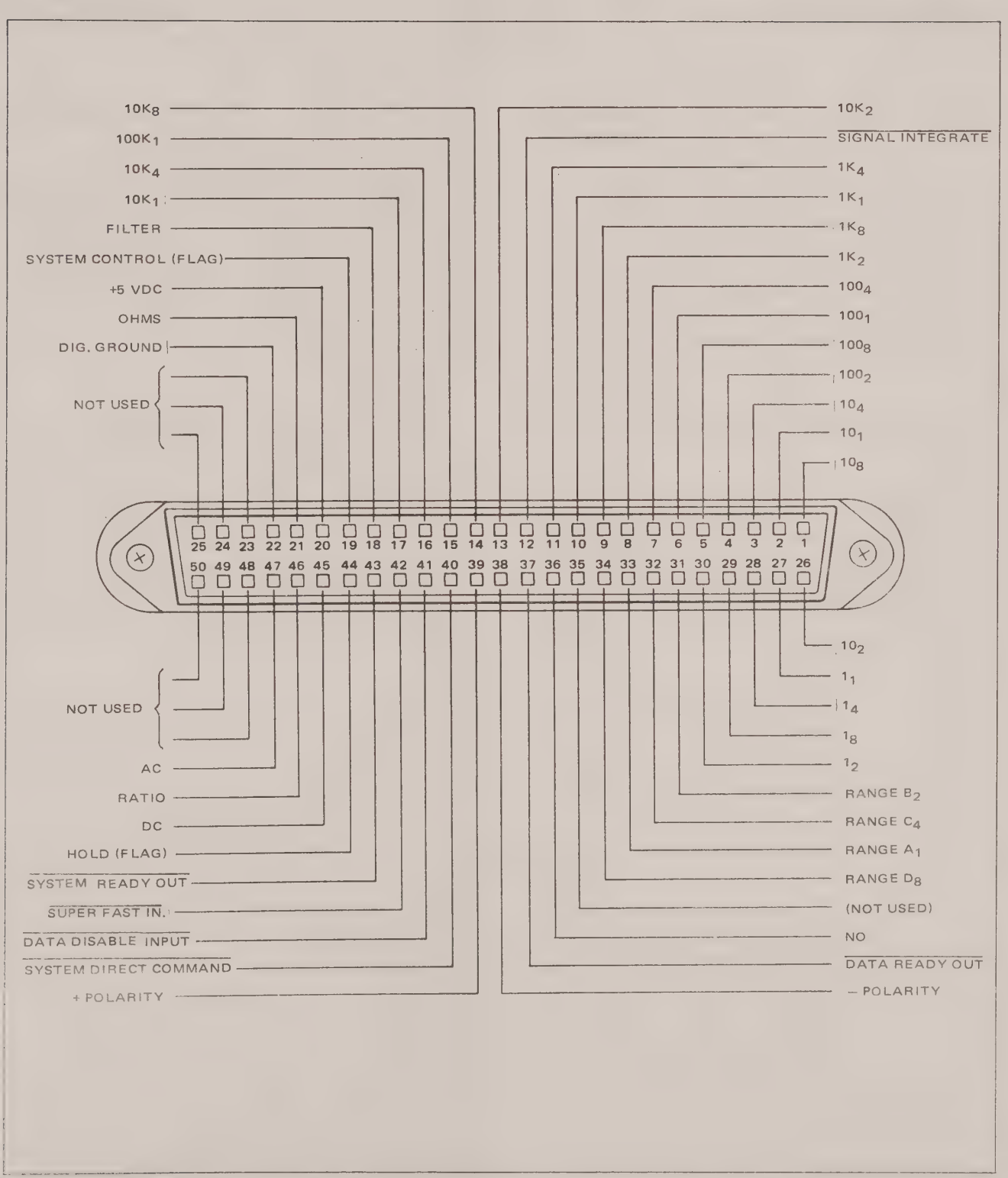


Figure 2.6 - J212 Parallel BCD Printer Output Connector (Rear Panel)

SECTION 3 OPERATION

3.1 INTRODUCTION.

3.1.1 This section contains operating and calibration information for the Model 6000 DMM. The operating information contains illustrations of all front and rear panel controls, indicators and connectors along with tabular listings of the function and purpose of each. Operating instructions for manual or bench operation are presented in two ways; a description of each operating feature followed, where necessary, with a step-by-step operating example. Some operating features or functions are simple one or two step operations and thus no operating examples are included.

3.1.2 Remote operation via the IEEE-STD-488-1975 General Purpose Interface Bus is one of the principal features of the 6000 DMM and the section presents bus address selection information and a tabular listing of the device-dependent messages used to program the instrument. Also included is a GPIB program, measurement and data transfer example in tabular form. This example is a step-by-step listing of the interface command messages, data messages and interface control signal line operation required to perform a typical program and data transfer cycle. A timing diagram accompanies the GPIB program cycle to illustrate the timing relationship of the interface, handshake and data lines of the bus in operation.

3.1.4 A calibration check procedure is provided and this procedure includes step-by-step instructions for the calibration check along with illustrations showing the connection of the 6000 DMM and the calibration equipment.

3.1.5 Following the calibration check procedure is a laboratory calibration procedure. This is a step-by-step procedure providing instructions for complete calibration of the instrument.

3.2 CONTROLS, INDICATORS AND CONNECTORS.

3.2.1 The location, nomenclature and function of all controls, indicators and connectors are illustrated and described in Figure 3.1 through 3.3 and the accompanying Tables 3.1 through 3.3. The front panel information is presented in Figure 3.1, Table 3.1; the keyboard information in Figure 3.2, Table 3.2 and, the rear panel is shown and described in Figure 3.3 and Table 3.3.

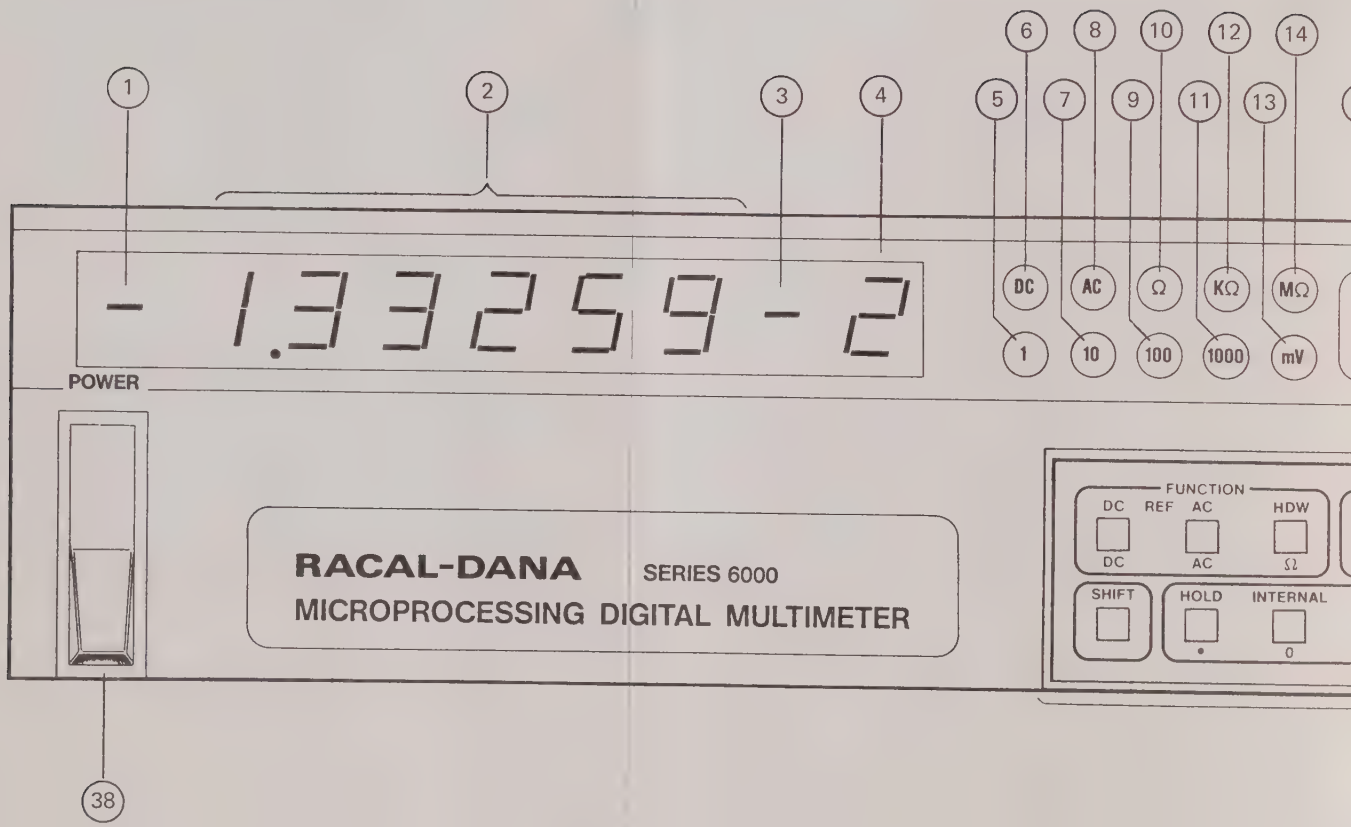
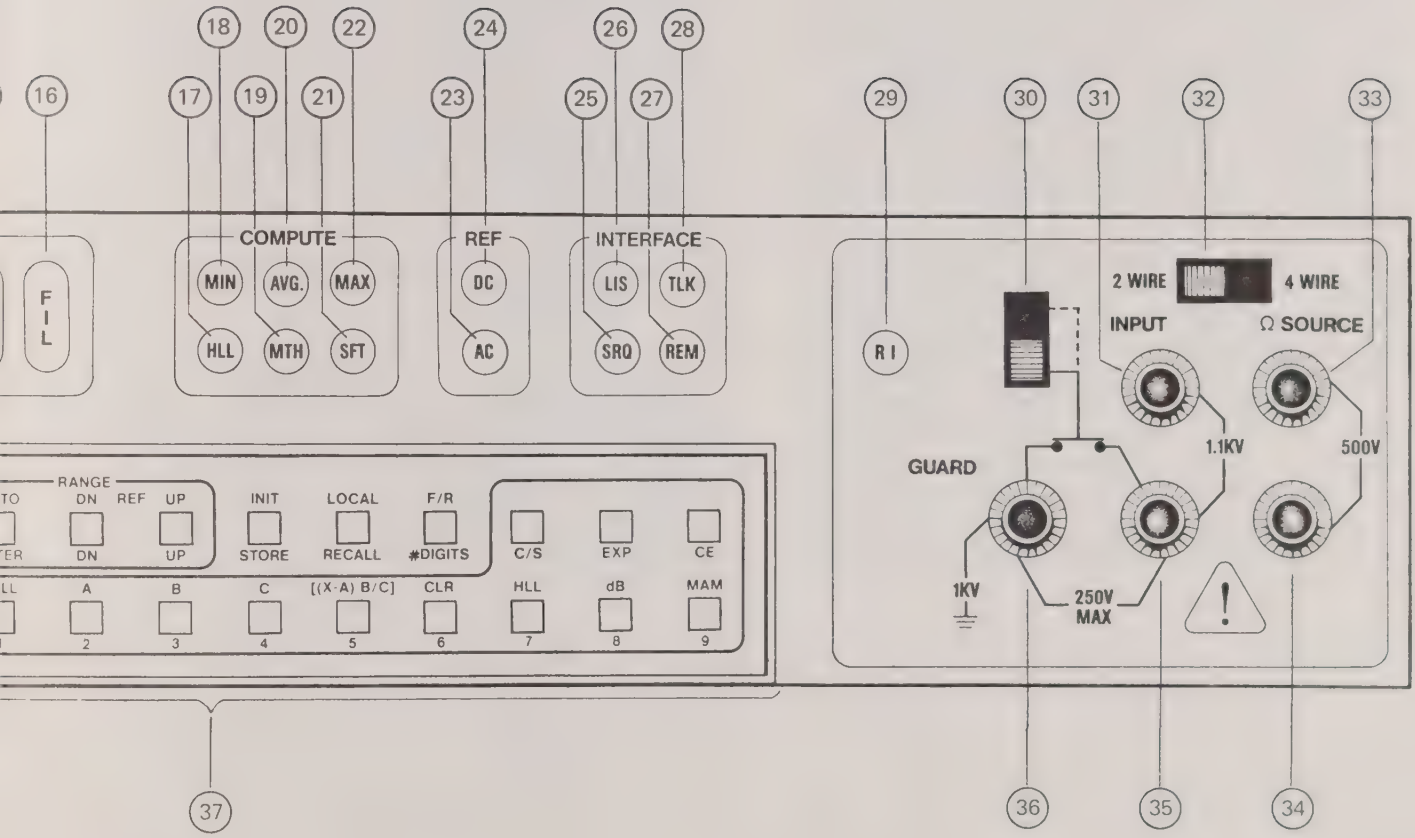


Figure 3.1 - Front Panel Controls, Indicators and Connectors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FIL
COMPUTE
MIN
AVG.
MAX
HLL
MTH
SFT
REF
DC
AC
INTERFACE
LIS
TLK
SRQ
REM
RI
2 WIRE
4 WIRE
INPUT
Ω SOURCE
GUARD
1.1KV
500V
1KV
250V
MAX
RANGE
DN
REF
UP
DN
UP
INIT
STORE
LOCAL
RECALL
F/R
#DIGITS
C/S
EXP
CE
A
B
C
[(X-A) B/C]
CLR
HLL
dB
MAM
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Table 3.1 - Front Panel Controls, Indicators and Connectors

Reference	Item/Position	Function
(1)	Mantissa sign indicator (LED)	Displays the – polarity of the mantissa appearing on the display LEDs.
(2)	Mantissa display LEDs	For the DC, AC and ohms functions these LEDs display the value of the measurement along with any appropriate decimal point. They are also used to display constants and function symbols such as "db", "Hi" and "Lo".
(3)	Exponent sign indicator	Displays the negative sign indication for the exponent.
(4)	Exponent indicator	Indicates the numeric value of the exponent. Also indicates LSD when in 6 1/2 digit mode.
(5)	1 range indicator LED	Indicates that the instrument is on the 1 volt range when on AC or DC functions or in the 1Ω , 1KΩ or 1 Megohm range in the resistance function.
(6)	DC annunciator	Indicates that the instrument is on the DC volt function.
(7)	10 annunciator	Indicates that the instrument is on the 10 volt or 10 mV range when on the AC or DC volts function or on the 10Ω, 10KΩ or 10 Megohm range in the resistance function.
(8)	AC annunciator	Indicates the instrument is performing an AC volts measurement function.
(9)	100 annunciator	Indicates the instrument is on the 100 volt or 100 mV range when performing an AC volts or DC volts measurement or on the 100Ω, 100KΩ or 100 Megohm range in the resistance function.
(10)	Ω annunciator	Indicates that the instrument is performing a resistance measurement function and that the display is indicating the value of the measurement in ohms.
(11)	1000 annunciator	Indicates that the instrument is on the 1000 volt range while performing in an AC volts or DC volts measurement.
(12)	KΩ annunciator	Indicates that the instrument is performing a resistance measurement function and that the value shown on the display is in kilohms.
(13)	mV	Indicates that the instrument is measuring DC volts and that the display is showing the voltage measurement in mV.
(14)	MΩ annunciator	Indicates that the instrument is performing a resistance measurement and that the display is indicating the resistance value in Megohms.
(15)	AUTO annunciator	Indicates that the instrument is in the auto range mode.

Table 3.1 - Front Panel Controls, Indicators and Connectors continued

Reference	Item/Position	Function
(16)	FIL indicator	Indicates that the input filter has been switched in the measurement input circuit.
(17)	HLL annunciator	Indicates that the instrument is performing the high-low-limit function. When this annunciator is lit it indicates that the display is showing a relative measurement of the value based on a preselected and preprogrammed input limit.
(18)	MIN annunciator	Indicates that the display is presenting the recalled minimum value measured during a min-avg-max measurement function. The min avg max are all lit when MAM routine is being used. Min lit by itself only during "Recall Min" operation.
(19)	MTH annunciator	Indicates that NULL or $\frac{(X-A)}{C}B$ is being used.
(20)	AVG annunciator	Indicates that the display is presenting the recalled average result of the min-average-maximum computation. The min avg max are all lit when MAM routine is being used. Avg lit by itself only during "Recall Avg" operation.
(21)	SFT annunciator	Indicates that the keyboard is in the SHIFT mode.
(22)	MAX annunciator	Indicates that the display is presenting the value of the highest measurement made during a min-average-maximum function. The min avg max are all lit when MAM routine is being used. Max lit by itself only during "Recall Max" operation.
(23)	AC REF annunciator	Indicates that the instrument is using an external AC reference voltage.
(24)	DC REF annunciator	Indicates that the instrument is using an external DC reference voltage.
(25)	SRQ annunciator	Indicates that the instrument is transmitting a service request (interrupt) to the controller in system operation.
(26)	LIS annunciator	Indicates that the instrument has been programmed by the controller to function as a listener on the General Purpose Interface Bus.
(27)	REM annunciator	Indicates that the instrument has been put into the remote operating mode by the controller (parallel BCD or GPIB) or by the operator via the keyboard (parallel BCD only).
(28)	TLK annunciator	Indicates that the instrument has been programmed by the controller to function as a talker on the General Purpose Interface Bus.

Table 3.1 - Front Panel Controls, Indicators and Connectors continued

Reference	Item/Position	Function
(29)	RI annunciator	Indicates that the instrument is in the rear input mode.
(30)	COMMON-GUARD switch	When set to the lower position this switch connects the input common to the guard terminal.
(31)	INPUT high connector	Serves as the front panel connection for DC volts, AC volts, millivolts and 2-wire resistance measurements.
(32)	2 WIRE/4 WIRE switch	When set to the 2 wire position this switch connects the ohms source terminals to the input terminals to facilitate convenient 2 wire resistance measurements. When set to the 4 wire position, the ohms source terminals are disconnected from the input terminals. When used in the 4 wire position the instrument must be connected to the unknown resistance via 4 input connection leads. This switch should be in the 4-wire position when measuring High Voltage AC or DC (> 500V). The 2-wire/4-wire Operation is explained in paragraph 3.3.6, page 3-13.
(33)	OHMS SOURCE connector	Provides the output source current for resistance measurement.
(34)	OHMS SOURCE low connector	Provides the source current for resistance measurements.
(35)	INPUT low connector	Provides the front panel input connection for AC volts, DC volts, millivolts and ohms 2-wire resistance measurements.
(36)	GUARD connector	Provides the front panel connection for the guard plane of the instrument.
(37)	Keyboard	Provides operate control of all instrument functions in local mode. Functions of the individual pushbuttons on the keyboard are described in Table 2.
(38)	PWR switch/indicator	Lights the switch and applies main AC line power to the instrument when set to the ON position. Causes the DMM to perform the following Initialization Sequence: a. Performs Auto-Test/Auto-Cal. b. Sets DMM to Internal Reference, DC Volts, Auto-range and Continuous Readings.

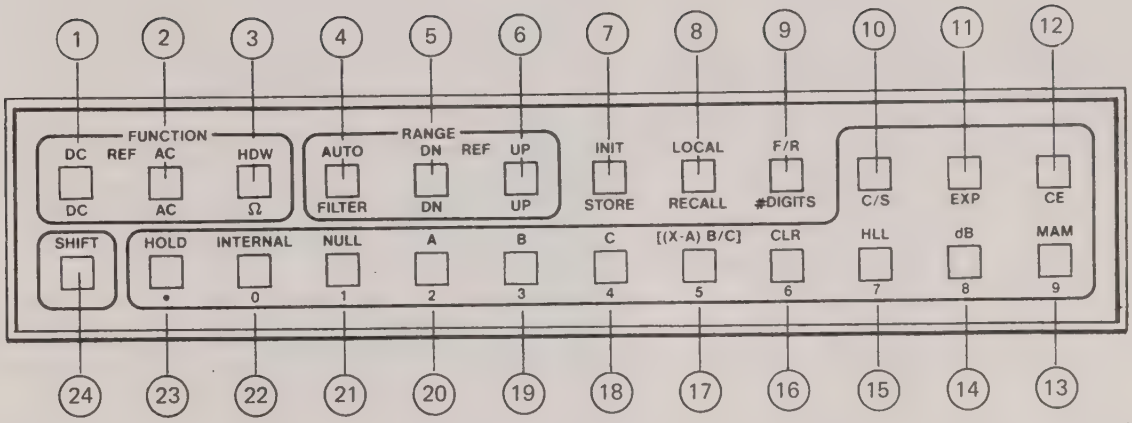


Figure 3.2 - Keyboard Control Layout

Table 3.2 - Keyboard Control Functions

Reference	Control	Function
(1)	DC	Selects the DC volts/millivolts function and puts the instrument in AUTO range.
	SHIFT DC	Selects the Software Ratio function, DC reference (applied to deselected input).
(2)	AC	Selects the AC volts function and puts the instrument in AUTO range. Requires Option 10 or Option 14.
	SHIFT AC	Selects the Software Ratio function, AC reference (applied to deselected input). Requires Option 10 or Option 14.
(1)	SHIFT HDW DC	Selects DC external reference voltage at EXT REF terminals and 4-wire DC ratio mode (Option 34) for hardware ratio measurements.
(2)	SHIFT HDW AC	Selects AC external reference voltage at EXT REF terminals. (Requires Option 11 for hardware ratio measurements.)
(1) (2)	SHIFT HDW THEN DC AC SIMULTANEOUSLY	Prepares instrument for external reference selection. Pressing both keys simultaneously selects DC coupled AC external reference voltage at EXT REF terminals (Option 11) for hardware ratio measurements.
(1) (2)	SIMULTANEOUSLY DC AC	Pressing both keys simultaneously selects DC coupled AC when True RMS Converter (Option 10) is installed.
(3)	Ω	Selects the resistance function and puts the instrument in AUTO range. (Requires Option 24.)
(4)	FILTER	Toggles the 4-pole active filter (on, off, on, etc.).
	SHIFT AUTO	Toggles the AUTO range function (on, off, on, etc.).
(5)	SHIFT DN	Causes the reference voltage range to down-range on each depression and causes the instrument to display the range of the reference voltage on the range annunciators for as long as the key is held down.
	DN	Takes the instrument out of AUTO range (if in auto) on first depression. Each subsequent depression causes the instrument to down-range.

Table 3.2 - Keyboard Control Functions continued

Reference	Control	Function
(6)	SHIFT + UP	Causes the reference voltage range to up-range on each depression and causes the instrument to display the range of the reference voltage on the range annunciators for as long as the button is held down.
	UP	Takes the instrument out of AUTO range (if in auto) on first depression. Each subsequent depression causes the instrument to up-range.
(7)	SHIFT + INIT	Takes the instrument out of high level function modes and returns it to internal reference.
	STORE + (X)	Causes the instrument to store the previous reading or the value shown on the display into the location determined by the operator. Storage location selection is accomplished by depressing one of the keys: A B C dB HLL *
(8)	SHIFT + LOCAL	Sends an RTL (return to local) request to the systems interface. Returns the instrument to local operation unless the instrument has been given a local lockout (LLO) command. Holding the button down causes the instrument to display the GPIB device address on the readout.
	RECALL + (X)	Causes the instrument to recall and display the present value stored in anyone of the following locations: A B C dB NULL MAM HLL *
(9)	SHIFT + F/R	Toggles the front/rear relay so that either input may be used for measurement. When the rear input is in use the RI indicator on the front panel is lit (reference 29, table 3-1).
	#DIGITS + 4 / 5 / 6	Selects the display length, integration time and causes the instrument to perform an Auto-Test/Auto-Cal routine. After depressing the number of digits pushbutton the 4, 5 or 6 button must be depressed to select the number of digits.
(9)	#DIGITS + 0	Disables Auto-Test/Auto-Cal until SHIFT/INIT is pressed.
(9)	#DIGITS + 3	Causes the output of the Fast A/D converter to be displayed in signed octal.
(10)	C/S	The "change sign" pushbutton reverses the polarity of entered mantissas and exponents.
(11)	EXP	Enables the entry of exponents. The depression of this key signals the instrument that numbers to follow are to be stored as exponents.
(12)	CE	"Clear Entry Key" clears the numbers in display and returns the machine to its previous state.

*Reference HLL operating procedure (page 3.16)

Table 3.2 - Keyboard Control Functions continued

Reference	Control	Function
(13)	SHIFT + MAM	Toggles the MAM function. MIN, AVG and MAX annunciators are lit while the MAM function is selected.
	9	Enters the digit 9 which will then be displayed until it is assigned a memory location.
(14)	SHIFT + dB	Toggles the dB function. This function displays the measurement value in decimals referenced to 1 milliwatt in 600 ohms. (The resistance value may be changed to any desired value; see the Decibel operating procedure (page 3.21).
	8	Enters the digit 8 which will then be displayed until it is assigned a storage location.
(15)	SHIFT + HLL	Toggles the HLL function. See the hi/low limit operating procedure.
	7	Enters the digit 7 which will then be displayed until it is assigned a memory location.
(16)	SHIFT + CLR	Causes the selected storage register to be set to a value which least affects the display as follows: SHIFT + CLR + [(X-A) B/C] — Sets A to 0, B and C to 1.0 SHIFT + CLR + A — Sets A to 0, B and C unaffected SHIFT + CLR + B — Sets B to 1.0, A and C unaffected SHIFT + CLR + C — Sets C to 1.0, A and B unaffected SHIFT + CLR + MAM — Clears the min, max and average SHIFT + CLR + dB — Sets R to 600 ohms (0 dB = 1 mW into 600Ω)
	6	Enters the digit 6 which will then be displayed until it is assigned a memory location.
(17)	SHIFT + [(X-A) B/C]	Causes the instrument to perform the mathematical formula indicated above the key. X is the present measurement value (reference Figure 3.9). When selected, the constant stored in memory location A is subtracted from the present measurement value. The difference is then multiplied by the constant stored in memory location B and divided by the constant stored in memory location C. The values of A, B and C must have been entered prior to using the math function. The function may be exited by again pressing SHIFT + [(X A) B/C]. The constants will remain in memory until they are cleared or changed.
	5	Enters the digit 5 which will then be displayed until it is assigned a memory location.

Table 3.2 - Keyboard Control Functions continued

Reference	Control	Function
(18)	SHIFT □ C □	Used with the store and recall keys for entering or recalling values in the storage location C.
	□ 4	Enters the digit 4 which will then be displayed until it is assigned a memory location.
(19)	SHIFT □ B □	Used with the store and recall keys for entering or recalling values in the storage location B.
	□ 3	Enters the digit 3 which will then be displayed until it is assigned a memory location.
(20)	SHIFT □ A □	Used with the store and recall keys for entering or recalling values in the storage location A.
	□ 2	Enters the digit 2 which will then be displayed until it is assigned a memory location.
(21)	SHIFT □ NULL □	Causes the instrument to store the present measurement value for subtraction from all future readings and begins the null function. When the null function is in use the MTH annunciator is lit. Depressing the recall button and the null button will cause the instrument to display the values stored in the null constant storage location. Note: When the null function is activated, the 6000 should not be down-ranged below the voltage range in which the null function was originally activated. The function may be exited by again pressing SHIFT □ NULL □. The constant will remain in memory until it is cleared or changed.
	□ 1	Enters the digit 1 which will then be displayed until it is assigned a memory location.
(22)	SHIFT □ INTERNAL □	Enables the internal trigger of the instrument. This pushbutton is used to take the instrument out of the hold mode.
	□ 0	Enters the digit 0 which will then be displayed until it is assigned a memory location.
(23)	SHIFT □ HOLD □	Places the instrument in the "hold" mode (no internal trigger) and calls for a single measurement to be made and displayed.
	□ .	Enters the decimal character which will then be displayed until it is assigned a memory location.
(24)	SHIFT □	Toggles the keyboard shift. When in the shift mode the SFT annunciator is lit and the instrument interprets keyboard depression according to the shift (yellow colored) markings. For example, to initialize the instrument press the shift key so that the SFT annunciator lights then press the INIT/STORE key. To select the STORE function, the INIT/STORE push-button must be depressed while the SFT annunciator is extinguished.

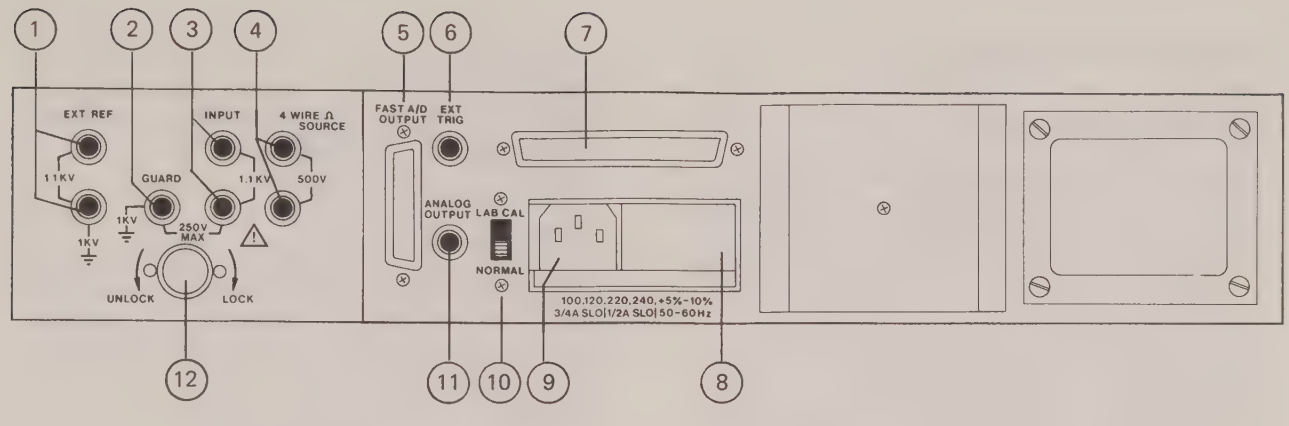


Figure 3.3 - Rear Panel Controls and Connectors

Table 3.3 - Rear Panel Controls and Connectors

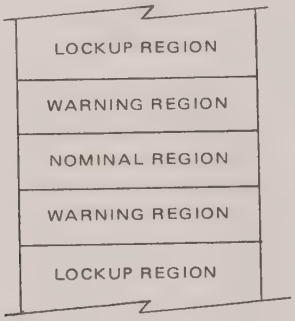
Reference	Item	Function
(1)	EXT REF input connectors	External reference input connectors for hardware ratio measurements.
(2)	GUARD connector	Provides rear panel connection for guard plane of the instrument.
(3)	INPUT connectors	Rear panel connection for AC volts, DC volts and 2-wire resistance measurements. Also may be used as a reference input when using automatic software ratio.
(4)	4 WIRE Ω SOURCE connectors	Provides the source current for 4-wire resistance measurements.
(5)	FAST A/D OUTPUT connector	Provides output connection for FAST A/D data if Option 03 or 03SH is installed. Provides programming input if Option 59 is installed. Pin signal assignment is presented in Section 2 of this manual.
(6)	EXT TRIG connector	Provides rear panel connection point for external trigger signal. (BNC connector)
(7)	GPIB or BCD Output connector	Provides interface bus connection. The connector is configured in accordance with IEEE 488-1975 standard digital interface if Option 55 is installed. It is the BCD output if Option 59 is installed. The pin signal assignments are presented in Section 2 of this manual.
(8)	Fuse holder	Fuse holder/safety interlock. Primary power fuse. Uses 3/4 amp slo blo fuse for 100-120 volt operation; 1/2 slo blo fuse for 220-240 volt operation.
(9)	Power connector	Connection point for primary AC power line cord.
(10)	LAB CAL/ NORMAL	Used for calibrating the instrument against lab standards. Not used for operation.
(11)	ANALOG OUTPUT connector	Provides rear panel connection of analog output signal (isolator output).
(12)	LOCK/UNLOCK knob	A mechanical fastener used to lock the calibration module in the instrument.

3.3 BENCH OPERATION.

3.3.1 Auto Test/Auto-Cal.

3.3.1.1 When the Model 6000 is initialized by power turn on (and at predetermined intervals after turn on) the Auto Test/Auto-Cal routines are performed. The type and number of routines are determined by the particular options installed in the DMM.

3.3.1.2 Each Auto Test/Auto-Cal routine is programmed to set the circuitry to a particular configuration and then take a reading. The reading is then compared to the applicable set of four limits stored in ROM. If the reading is within the Nominal Region a correction factor will be stored in memory and the next routine will be performed.



3.3.1.3 Readings which fall in one of the two Warning Regions will cause the DMM to momentarily display an error message before proceeding to the next routine. The temporary error message indicates that a larger than normal correction factor was required to bring the DMM readings within tolerance. The message is also an indication that the instrument should be scheduled for maintenance in the near future. Reference Table 3.7 for error messages.

3.3.1.4 Readings which fall in one of the Lockup Regions will cause the DMM to stop the Auto Test/Auto-Cal routines and display an error message. The error message and lockup condition indicate that the DMM should be scheduled for immediate maintenance because it cannot self correct to required tolerances. The lockup condition may be bypassed (for troubleshooting purposes) by pressing any key on the keyboard. Reference Table 3.7 for error messages.

3.3.1.5 If the Model 6000 is equipped with a GPIB (Option 55), any Auto Test/Auto-Cal related error message will cause an SRQ to be sent to the controller. A bit will also be set in the serial poll status byte (reference Figure 3.12). A lockup condition will also cause the GPIB to refuse acceptance of program codes. The GPIB will, however, still be able to output the serial poll status byte.

3.3.1.6 DC CAL.

3.3.1.6.1 The standard DMM will perform seven DC Cal routines (DC Cal 1 through DC Cal 7). If a Preamplifier (Option 41) is installed, the instrument will also perform the DC Cal 8 routine.

3.3.1.7 OHMS CAL.

3.3.1.7.1 The Model 6000 will perform five Ohms Cal routines (Ohms Cal 1 through Ohms Cal 5) when the Ohms board (Option 24) is installed. If a Preamplifier (Option 41) is also installed, the instrument will also perform the Ohms Cal 6 routine.

3.3.2 Range Control.

3.3.2.1 Upon initialization the instrument goes to its home state; autorange, DC volts and the range is set to whatever the instrument sees at the input terminals. For example, if a 1.5 volt battery is connected to the input terminal and the instrument is initialized by power turn on, the instrument will turn on, go through Auto-Cal routines and initialize in the home state (autorange, DC volts, 1 volt range).

3.3.2.2 To change the range manually depress the up or down keyboard buttons once to take the instrument out of autorange. This extinguishes the auto annunciator and the instrument will now respond to depression of the up or down keyboard buttons changing the range one increment for each depression.

3.3.2.3 To illustrate the manual range control sequence short the input terminals and apply power to the instrument. Note that it initializes in autorange on the 100 millivolt range. The instrument initializes to the range appropriate for the voltage it sees at the input terminals but it does not autorange down to the 10 millivolt range. Depressing the UP key once will extinguish the AUTO annunciator and put the instrument in manual range control mode. The next depression of the up pushbutton switches the instrument to the 1 volt range and each successive depression causes the

instrument to progress to the 10, 100 and the 1000 volt DC range. The instrument can be manually down ranged by depression of the down pushbutton. Each successive depression will cause the instrument to progress to the 100, 10, 1 and the 100 millivolt range. If the Millivolt DC Option (41) is installed the instrument may be manually downranged to the 10 millivolt range provided the input is less than 22 millivolts. If the input signal is over the 10 millivolt range the instrument will automatically uprange to the 100 mV range.

3.3.2.4 The instrument will go into autorange as a result of only 4 possible operations; 1) power on initialization, 2) manual depression of the SHIFT AUTO keyboard pushbuttons, 3) transmission of the autorange command by the controller in system operation and 4) a manual function change.

3.3.3 Autorange.

3.3.3.1 In the autorange mode except for the 10 millivolt DC and 1 ohm ranges, the instrument automatically changes its ranges as the measurement signal is increased above 160% of range. For example, when the instrument is on the DC 1 volt range in the autorange mode as the measurement voltage increases to approximately 1.6 volts the instrument will automatically switch to the 10 volt range. Conversely, as the voltage is decreased to approximately 1.4 volts the instrument will automatically downrange again to the 1 volt DC range. In the 10 millivolt and 1 ohm ranges the instrument automatically upranges at 220% of range. For best results, the DMM should be placed in manual ranging when switching inputs greater than 500 VDC.

3.3.4 DC Volts Measurement.

3.3.4.1 The Model 6000 basic instrument is capable of measuring DC volts in 5 ranges: 100 mV, 1V, 10V, 100V and 1000V. A 10 mV range is also available when the instrument is equipped with a Preamplifier (Option 41). To measure DC voltage proceed as follows:

1. Connect the instrument to the primary AC power source, turn the power switch on and allow it to initialize. Verify that the instrument initializes to the home state: DC volts function and AUTO range.

2. Set 2-wire/4-wire switch to 4-wire position if measuring voltages above 500V.

3. Connect the measurement voltage to the INPUT terminals and read the measurement value from the display and range annunciators.

3.3.5 AC Volts Measurement.

3.3.5.1 The Model 6000 instrument is capable of measuring AC RMS volts in 4 ranges: 1V, 10V, 100V and 1000V when equipped with either AC Option 10 (True RMS) or Option 14 (Averaging) AC converters. To measure AC voltage proceed as follows:

1. Connect the instrument to the primary AC power source, turn the power switch on and allow it to initialize. Verify that the instrument initializes to the home state: DC volts function and AUTO range.

2. Set 2-wire/4-wire switch to 4-wire position if measuring voltages above 500V.

3. Select the AC volts function by pressing the AC key and verify that the AC annunciator lites.

4. Connect the measurement voltage to the INPUT terminals and read the measurement value from the display and range annunciators.

> **NOTE**
>
> If the True RMS Option is installed the instrument can measure AC, DC or a signal composed of a DC voltage containing an AC component. To measure a signal containing both AC and DC components "DC coupled AC" mode must be selected.

3.3.5.2 To select DC coupled AC mode press the DC and AC keys simultaneously and verify that both the DC and AC annunciators come on.

3.3.6 Resistance Measurement.

3.3.6.1 The basic Model 6000 instrument is capable of measuring resistance in 8 ranges: 10Ω, 100Ω, 1KΩ, 10KΩ, 100KΩ, 1MΩ, 10MΩ and 100MΩ. A ninth range (1Ω) is available with the addition of Option 41. To measure resistance proceed as follows:

1. Connect the instrument to the primary AC power source, turn the power switch on and allow it to initialize. Verify that the instrument initializes to the home state: DC volts function and AUTO range.

2. Select the resistance function by pressing the Ω pushbutton and verify that one of the Ω annunciators (Ω, KΩ or MΩ) lites.

3. TWO-WIRE MEASUREMENTS.

a. Connections for a simple two-wire shielded ohms measurement are shown in Figure 3.4. It consists simply of a single-conductor shielded cable with the conductor serving as both the + Ω SOURCE and + INPUT leads and the shield carrying – Ω SOURCE and – INPUT. If front panel terminals are used, connections between + INPUT and + Ω SOURCE, and – INPUT and – Ω SOURCE can be made by setting the 2-WIRE/4-WIRE Switch to the 2-WIRE position. While reasonably accurate measurements can be made with this method, shunt leakage problems result from the parallel combinations of R_X and the cable impedance. This causes loss of accuracy, especially at high resistance (100 MΩ range). Also, lead resistance becomes a factor in the 1, 10 and 100 ohms ranges; the four wire measurement system is recommended for these ranges.

b. A more accurate two-wire measurement connection is shown in Figure 3.4b. The + INPUT and +Ω SOURCE, – INPUT and – Ω SOURCE terminals are again tied together. But now, the positive side is a single-conductor, shielded cable with the shield tied to Ohms Guard. Ohms Guard is the low ANALOG OUTPUT terminal on the rear panel of the Model 6000 when ohms is selected. The negative side is a single wire connected as shown. Guard current is present in the low side, but the leakage problems of the first configuration are eliminated.

c. In high noise-level environments, the configuration shown in Figure 3.4c is recommended. This method also eliminates error due to shunt leakage, but provides more complete shielding. The positive terminals are tied together and carried in a single-conductor, double-shielded cable with the inner shield tied to Ohms Guard (– ANALOG OUTPUT). The outer shield is tied to GUARD. The negative terminals are tied together and carried in a single-conductor shielded cable with the shield tied to GUARD. This configuration eliminates guard current sensitivity, thereby increasing guarding characteristics.

4. FOUR-WIRE MEASUREMENTS.

a. In most system applications, the device to be measured is located at a remote location requiring interconnection by cables of lengths from several to possibly hundreds of feet. When measuring low resistance values over long cables, most lead resistance problems can be solved by the use of a four-wire measurement system. If front panel terminals are used, set the 2-WIRE/4-WIRE Switch to 4-WIRE position.

b. For high resistance measurements over long cables, other problems are encountered: noise pick-up, leakage resistance, and capacitive loading of the system. These problems can be minimized by proper shielding and the use of ohms guard.

c. Figure 3.5a shows a basic shielded four-wire ohms measurement configuration. This method uses two single-conductor shielded teflon cables. The conductors carry the positive sides of the INPUT and CURRENT lines while each shield carries the low side.

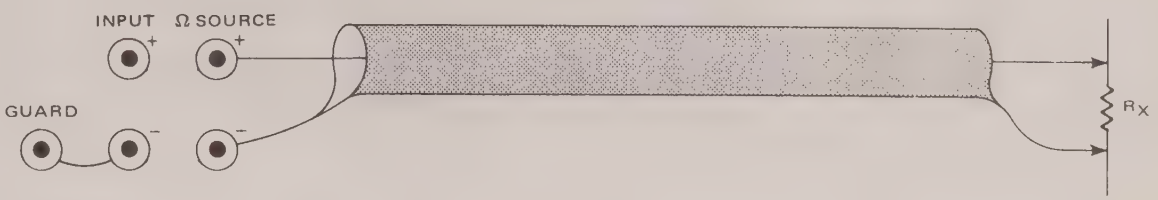
d. This configuration, although shielded, places the shield capacitance and cable leakage in parallel with R_X. This results in loss of accuracy and slow measurements. In addition, it is very responsive to the triboelectric effect at high resistance measurements.

e. Better guarding is achieved by the use of the configuration shown in Figure 3.5b. Here again, RG196U teflon dielectric cable (either single-conductor shielded or two-conductor shielded) is used on the positive terminals. The shield(s) are connected to Ohms Guard (low ANALOG OUTPUT terminal). The negative leads are single wires with the – INPUT terminal tied to GUARD.

f. This eliminates much of the shunt leakage problem of the previous configuration since guard current now flows through the low side of the measurement circuit. Measurement is much faster since the shield capacity is driven by the guard current.

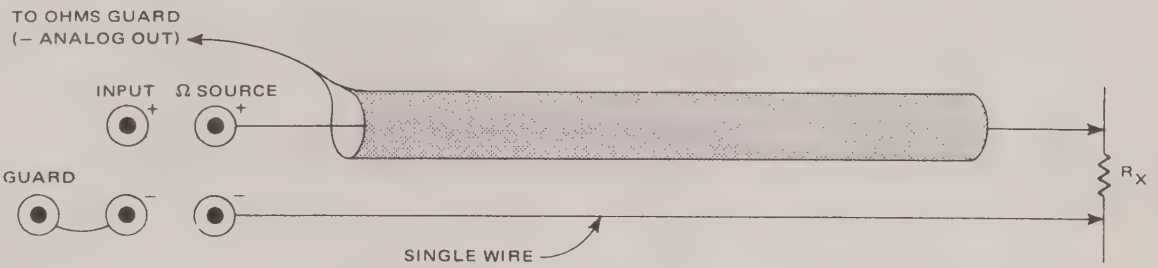
g. A high-noise environment calls for the "super" configuration shown in Figure 3.5c. Here, a two-conductor, double-shielded cable is used as the positive leads. The inner shield is tied to Ohms Guard. A two-conductor shielded cable is used as the negative leads. Its shield is tied to GUARD and to the outer shield of the positive cable. The shield is also tied to – Ω SOURCE at the measurement point. This configuration maintains high guarding characteristics while eliminating guard current sensitivity.

(a)



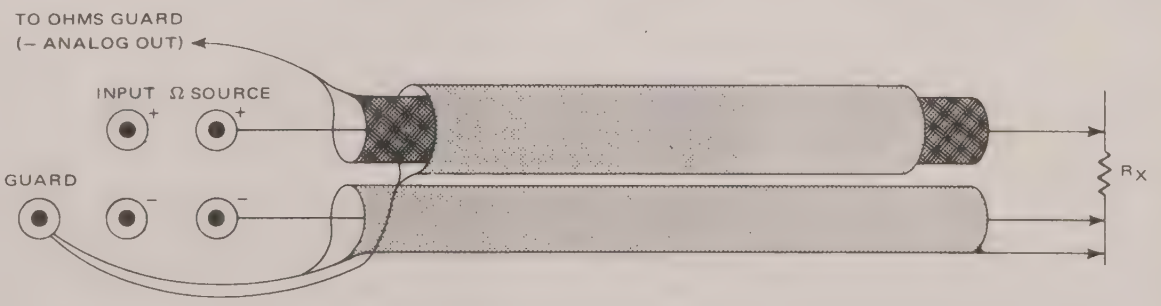
USED FOR NORMAL MEASUREMENTS ON ALL BUT THE 10 and 100Ω RANGES.
(FOR REAR PANEL INPUTS CONNECT + INPUT TO + Ω SOURCE – INPUT TO – Ω SOURCE)

(b)



USED ON 100 MΩ RANGE WHERE CABLE LEAKAGE IS A PROBLEM.
(FOR REAR PANEL INPUTS CONNECT + INPUT TO + Ω SOURCE – INPUT TO – Ω SOURCE)

(c)



USED ON 100 MΩ RANGE IN HIGH-NOISE ENVIRONMENT; MINIMIZES BOTH NOISE AND LEAKAGE PROBLEMS.
(FOR REAR PANEL INPUTS CONNECT + INPUT TO + Ω SOURCE – INPUT TO – Ω SOURCE)

Figure 3.4 - Two Wire Ohms Measurements

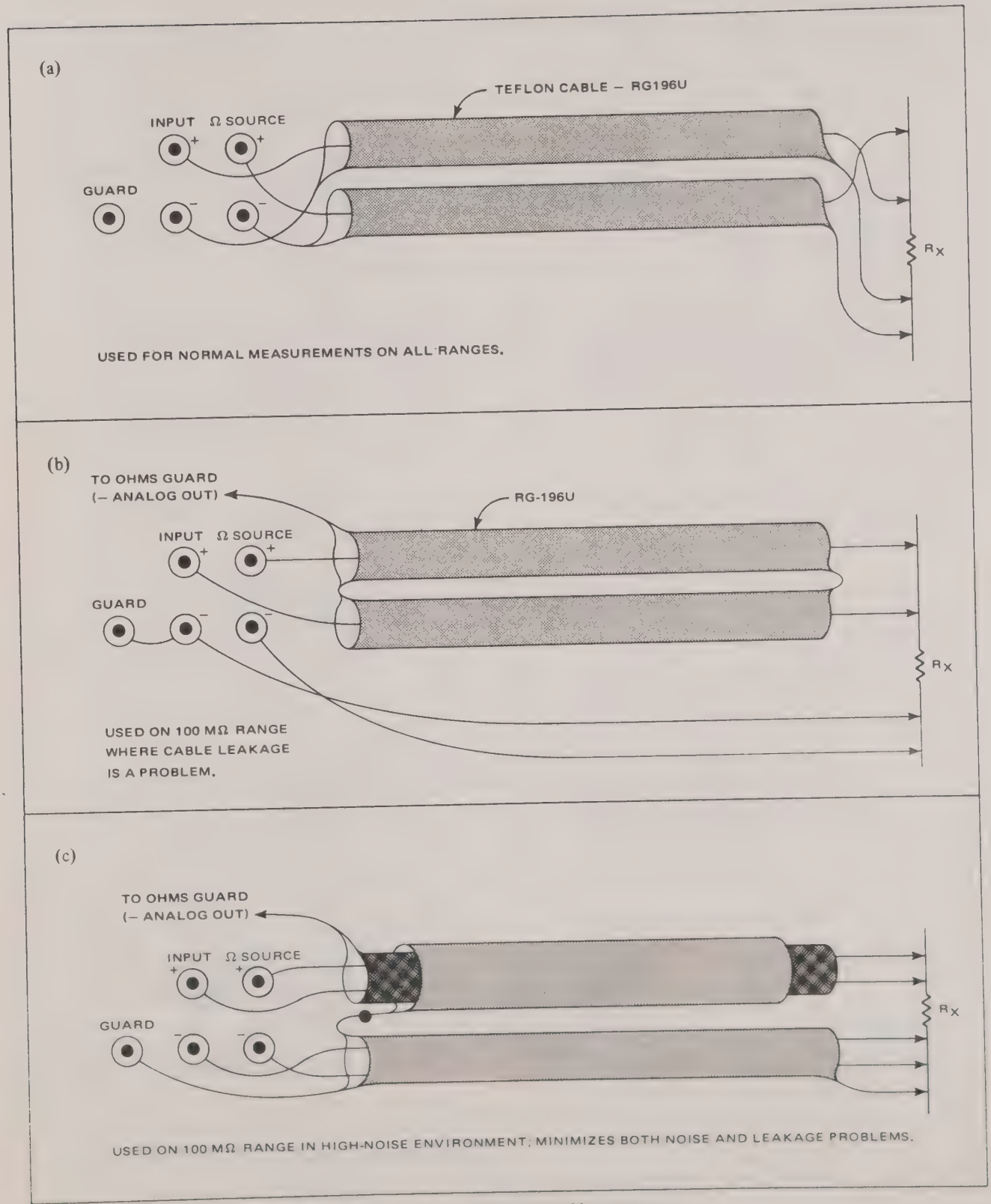


Figure 3.5 - Four Wire Ohms Measurement

5. If measuring on 1Ω range, disconnect the +I (+ current) lead at the Voltmeter terminal. Wait until the display value is stable within ± 5 digits and press NULL key. Reconnect the +I lead and read the value from the display. Extreme care must be exercised to avoid generating thermal voltages between connection points. Use cables with Kelvin clips, or other low thermal terminations at resistor connection points.

6. Read the measurement value from the display and range annunciators.

3.3.7 High-Low-Limit Operation.

3.3.7.1 The high-low-limit (HLL) function provides two basic modes of operation. The first mode is the one or two limit, two or three category mode which compares the measurement with preprogrammed limits entered by the operator. The second HLL mode is the three to five limit, four to seven category mode. In this mode the operator enters between three and five limits and the instrument will then compare the input measurement with these limits and categorize the input into four to seven categories.

3.3.7.2 SINGLE OR DUAL LIMIT.

3.3.7.2.1 This is the simplest mode of HLL operation. In this mode the operator enters an upper and lower limit into memory and selects HLL operation mode. The instrument then compares each measurement to the lower and upper limit and presents the message Lo, Pass or Hi on the front panel display.

3.3.7.2.2 For example, if the operator wanted to verify that a voltage falls between 4 and 5 volts DC, he simply enters 4 as the lower limit and 5 as the upper limit; once the HLL mode is selected any measurement falling below 4 volts will cause the display to present the message Lo, any measurement voltage between 4 and 5 volts will cause the display to present the message PASS, while any measurement voltage above 5 volts causes the display to present the message HI as shown in Figure 3.6 .

3.3.7.2.3 If it is desired to set only one boundary limit the instrument will present only two messages. For example, to determine whether a measurement is higher than a predetermined minimum the limit is entered in limit location 1 and for measurements falling under the limit the instrument will display the message Lo. For a measurement above the limit the instrument will display the PASS message. Similarly if the single limit is entered in location 2 the instrument will display the PASS or HI messages.

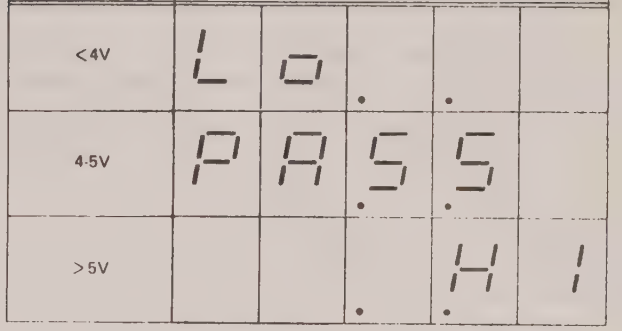
MEASUREMENT VALUE	HLL DISPLAY
<4V	
4-5V	
>5V	

Figure 3.6 - LO-PASS-HI Displays

3.3.7.2.4 At this time it should be pointed out that the HLL mode is useable with AC volts, DC volts, resistance and ratio measurements. Further, the operator may set the parameters for limits as tightly or as broadly as desired. The pass category may be set so that the lower limit and upper limit are only a few microvolts apart. On the other hand, the lower and upper limits may be set hundreds of volts apart, depending on the requirements of the measurement application.

3.3.7.2.5 The measurement value or ratio value (defined as X) may be part of the mathmatical function (X-Null) - (A x B ÷ C). In this case, the scaled values of X will be tested against the HLL limits.

3.3.7.3 SEVEN BIN SORT OPERATION.

3.3.7.3.1 The multiple category HLL operation is selected automatically whenever the operator enters more than 2 limit parameters. In the multiple category HLL mode the instrument can present up to 7 display messages as shown below.

3.3.7.3.2 To illustrate the application of this measurement sorting function, referred to as HLL, assume that it is

LIMIT MEMORY LOCATIONS	5	3	1	2	4	6	
DISPLAY CATEGORIES	Lo..	c..	b..	.A.	..b	..c	..HI
LIMITS (VOLTS OR OHMS)	2	3	4	5	6	7	

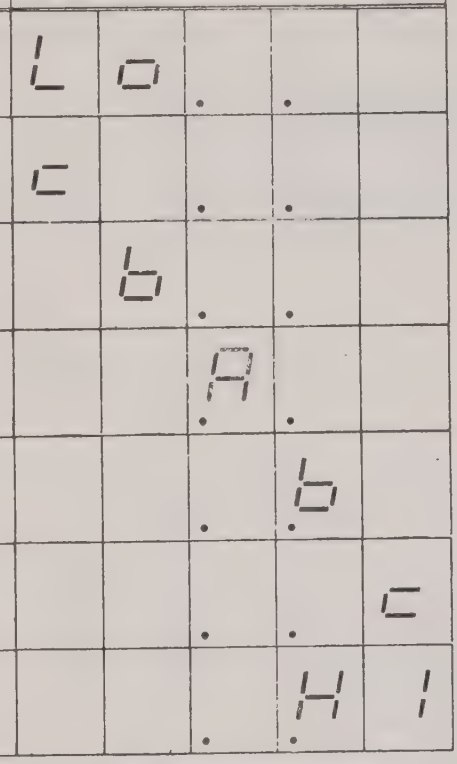
MEASUREMENT VALUE	HLL DISPLAY
<2V	
2-3V	
3-4V	
4-5V	
5-6V	
6-7V	
>7V	

Figure 3.7 - Seven Bin Sort Display Examples

desired to fit measurements into the seven categories shown by the limits in Figure 3.6. The limits could be applicable to AC or DC voltages or to resistance values in ohms. For the sake of discussion assume that the limits shown in the illustration represent DC voltage limits. Note that the "A" category falls between the 4 and the 5 volts. This is common TTL logic voltage. Note also that the other six categories fall between 1 volt steps. Note also that the voltage limits selected increase in voltage from left to right. It is absolutely essential that limits be entered into limit locations in ascending values with the more negative or lower value on the left and the more positive or higher value on the right.

3.3.7.3.3 To make the limit locations easier for an operator to memorize the storage locations have been numbered as shown; the centered limit A is bracketed by limit locations 1 and 2. The neighboring lower and higher limit locations are bracketed on the left by the odd numbers 3 and 5 and on the right by the even numbers 4 and 6. In the example shown all voltages are entered as positive voltages between 2 and 7 volts. Note that the center voltage category "A" is between 4 and 5 volts while the next lower category is between 3 and 4 volts. With limits entered into locations as shown the instrument will display the message LO for any voltage less than 2 volts and the message HI for voltage higher than 7 volts. Measurement voltages falling between 2 and 6 volts will be displayed as upper case A, lower case b or c. Figure 3.7 illustrates the display presented for the measurement inputs shown. Note that there are two lower case b categories and two lower case c categories. These may be distinguished from one another by their location on the display relative to the two flashing decimals adjacent to the category A display location.

3.3.7.3.4 Table 3.4 presents a step-by-step operating sequence demonstrating operation of the Series 6000 DMM in the HLL mode.

3.3.8 Minimum-Average-Maximum.

3.3.8.1 The Series 6000 DMM provides a minimum-average-maximum (MAM) measurement capability. When used in this mode the instrument performs the following operations: a) stores the least positive (or most negative) value measured during the MAM operating cycle, b) stores the value of the most positive (or least negative) measurement made during the MAM cycle, c) calculates the average value of all measurements taken during the MAM cycle, d) counts the number of total measurements made during the MAM measurement cycle.

3.3.8.2 To accomplish this function, the instrument makes the first measurement and stores it. It then compares each successive reading with the previous measurement to determine whether the present reading is higher or lower than the previous reading. If the second reading is lower than the first, the instrument will store the present reading in the Min memory location. The instrument will also perform an arithmatic average on the two readings and store the result in the Avg memory location. The machine then makes a new measurement, performs the comparison again and, if the new measurement is higher or lower than a previous reading it is stored in the Min or Max memory location. The instrument uses a fourth memory location to store the count of the number of measurements made during the MAM measurement cycle.

3.3.8.3 In a typical application, the instrument may be connected to another device or system and used to monitor a power supply voltage or the AC line voltage over a period of time. The operator can leave the instrument unattended and return at a later time and recall the minimum voltage level the average of all measurements made, the maximum voltage level and the total number of measurements made. Table 3.5 presents a step-by-step operating procedure for using the 6000 in the MAM mode.

> **NOTE**
>
> The MAM function will update the minimum and maximum readings indefinitely, but will not update the average or the number of measurements readings beyond the first 10,000 samples.

Table 3.4 - Example of HLL Operating Procedure

Step	Equipment Connection	Control or Key	Display and Annunciators	Function or Interpretation
1	AC Power			
2		POWER ON	Initialization Sequence - See Table 3.1, Reference 38	
3	4.5 VDC to Input		4.5XXX (DC) (10) (AUTO)	Display indicates input voltage
4		□ 4	4.	Enters 4 volt limit
5		□ STORE	4. (DC) (10) (AUTO) (SFT)	Instructs instrument to store value on display when location entered
6		HLL □	HL (DC) (10) (AUTO)	Selects HLL limit storage area for storage
7		□ 1	4.5XXX (DC) (10) (AUTO)	Selects HLL storage location 1, stores value entered (4) and returns to DC, 10, AUTO
8		□ 5	Display and annunciator sequence similar to steps 4 thru 7 except for values and storage locations	This Key entry sequence stores the limit value 5 in HLL location 2 as described in steps 4 thru 7
9		□ STORE		
10		HLL □		
11		□ 2		
12		□ 3		Stores value 3 in HLL limit location 3
13		□ STORE		
14		HLL □		
15		□ 3		

Table 3.4 - Example of HLL Operating Procedure continued

Step	Equipment Connection	Control or Key	Display and Annunciators	Function or Interpretation
16		□ 6		Stores value 6 in limit location 4
17		□ STORE		
18		HLL □		
19		□ 4		
20		□ 2		Stores value 2 in limit location 5
21		□ STORE		
22		□ HLL		
23		□ 5		
24		□ 7		Stores value 7 in limit location 6
25		□ STORE		
26		□ HLL		
27		□ 6		
28		SHIFT □	4.5XXX (DC) (10) (AUTO) (SFT)	Selects upper case key functions
29		HLL □	.A. (DC) (10) (AUTO) (HLL)	Selects HLL function
30	The instrument is now ready to perform the HLL function. If the input voltage is varied the instrument will present display messages from Lo to HI as described in previous paragraphs.			
31	The function may be exited by again pressing SHIFT □ HLL □. The constants will remain in memory until they are cleared or changed.			
32	The constants may be cleared by pressing SHIFT □ CLR □ HLL □.			

Table 3.5 - Example of MIN-AVG-MAX Operating Procedure

Step	Equipment Connection	Control or Key	Display and Annunciators	Function or Interpretation
1	AC Power			
2		POWER ON	Initialization sequence - see Table 3.1, Reference 38	
3	4.5 VDC to INPUT		4.5XXX DC 10 AUTO	Display indicates input voltage
4		SHIFT	4.5XXX DC 10 AUTO SFT	Selects upper case keyboard functions
5		MAM	4.5XXX DC 10 AUTO MIN AVG MAX	Selects the Min-Avg-Max function
6	Allow the instrument to measure the input voltage for approximately one minute while varying the input voltage between approximately 4 and 5 VDC.			
7		SHIFT	4.5XXX DC 10 AUTO	Selects upper case keyboard functions
8		MAM		Toggles the instrument out of MAM function
9		RECALL MAM	4.XXX DC 10 AUTO MIN	Display indicates lowest measurement value recorded during MIN-AVG-MAX function
10		RECALL MAM	4.5XXX DC 10 AUTO AVG	Display indicates average measurement value of all measurements recorded during MIN-AVG-MAX function
11		RECALL MAM	4.XXX DC 10 AUTO MAX	Display indicates maximum measurement value recorded during MIN-AVG-MAX function
12		RECALL MAM	XXX n	Display indicates number of measurements made during MIN-AVG-MAX cycle
13	The MAM measurement values may be cleared by pressing SHIFT CLR MAM. The MAM function may be reentered without first clearing the measurement values. In this case, the present MAM values will be updated by the new readings.			
14	The MAM measurement values may be recalled, without leaving the function, by performing steps 9 thru 12. The MAM function will stop during the recall period, but it may be started again by pressing CE.			

3.3.9 Tri-Function Ratio.™

3.3.9.1 The Series 6000 can operate in three different ratio modes: Math Ratio, Automatic Software Ratio and Hardware Ratio (Option 34).

3.3.9.2 MATH RATIO.

3.3.9.3 The Math Ratio is provided as a part of the standard Series 6000, and fits the following formula:

$$R = \frac{X}{C}$$

Where: X = the measured input
C = the stored constant
R = the displayed ratio

An example of the Math Ratio key sequence is shown below.

SHIFT CLR [(X-A) B/C]	Clears constants A, B and C.
6 STORE C	Stores constant "6" in memory location C.
SHIFT [(X-A) B/C]	Display reading will now equal the measured input divided by 6.

3.3.9.4 SOFTWARE RATIO.

3.3.9.5 The Software Ratio is also a part of the standard DMM. The input signal and the reference signal are connected to the DMM input terminals (one signal to the front and one to the rear). Ratio mode is entered by selecting SHIFT AC (for AC reference signal) or SHIFT DC (for DC reference signal). The instrument will alternately measure the front and rear inputs and perform a ratio calculation. The relationship of the inputs in the ratio calculation is dependent upon the status of the (RI) (rear input) annunciator. The table shown below illustrates the signal relationships for the on-off conditions of the (RI) annunciator.

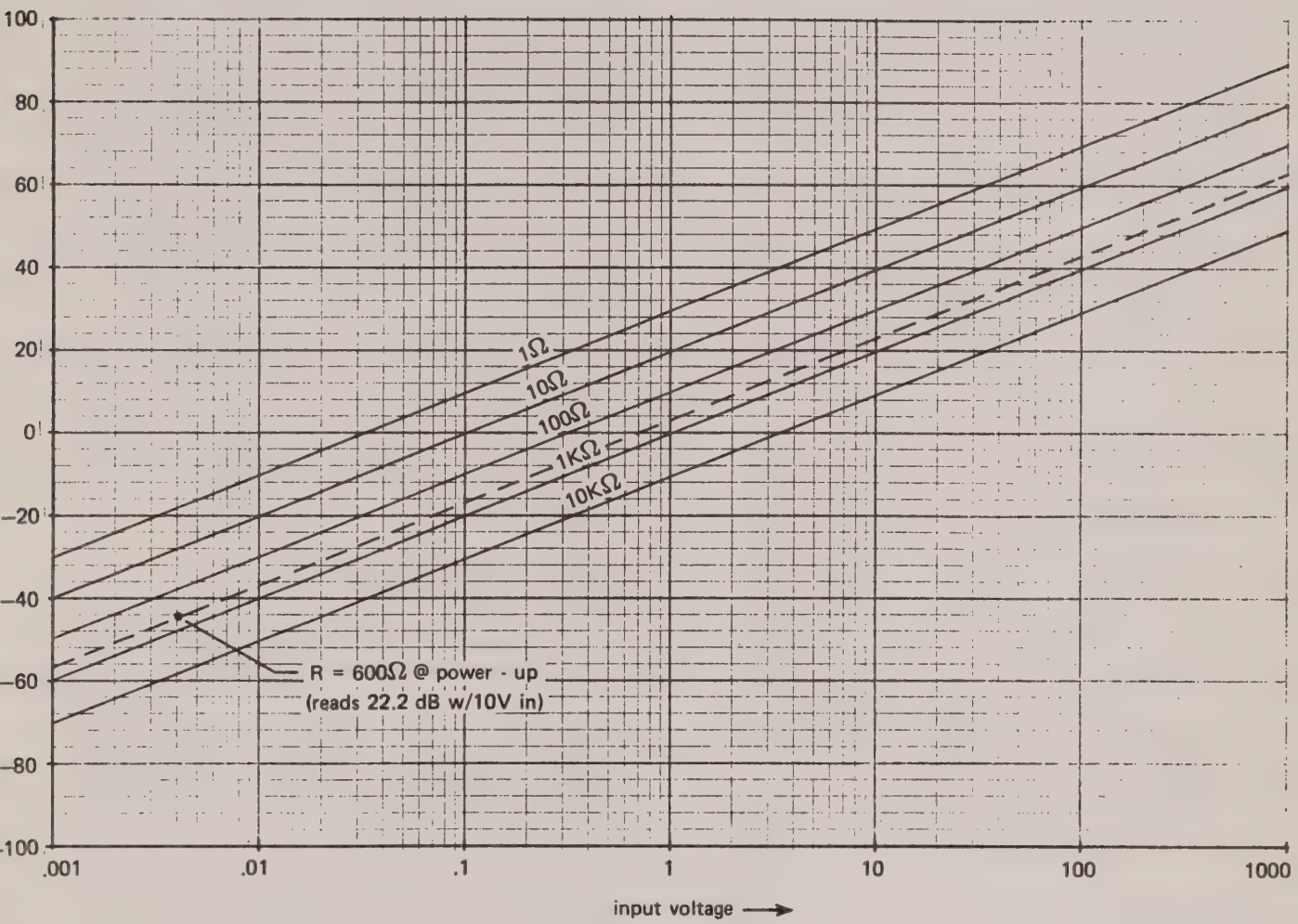
(RI) Annunciator Condition	Front Input Terminals	Rear Input Terminals	Ratio Displayed
Off	Measurement Signal	Reference Signal	Ratio = Front / Rear
On	Reference Signal	Measurement Signal	Ratio = Rear / Front

An example of the software ratio procedure is shown in Table 3.6.

Table 3.6 - Example of Software Ratio Operation

Step	Equipment Connection	Control or Key	Display and Annunciators	Function or Interpretation
1	AC Power			
2		POWER — ON	Initialization Sequence - See Table 3.1, Reference 38	
3	28V DC to Front INPUT Terminals		28.XXX (DC) (100) (AUTO)	
4	7 VDC to Rear INPUT Terminals		28.XXX (DC) (100) (AUTO)	
5		SHIFT DC	4 (DC) (100) (AUTO)	Display = Front Input/Rear Input
6		SHIFT F/R	.25 (DC) (100) (AUTO) (RI)	Note: Each depression of SHIFT F/R causes the (RI) annunciator to go on and off. Press F/R so that (RI) is ON thereby selecting rear input. .
7		SHIFT F/R	4 (DC) (100) (AUTO)	Select Front Input ((RI) off).

Formula for V-dB



Internal Reference	External Reference
$\text{display} = 10 \log \left[\frac{\text{input power in mW}}{1 \text{ mW}} \right]$	$\text{display} = 20 \log \frac{V_1}{V_2}$ V_1 = signal V_2 = reference voltage

Figure 3.8 - dB vs Voltage

3.3.9.6 HARDWARE RATIO (OPTIONS 34 AND 11).

3.3.9.7 The Model 6000 is capable of performing hardware ratio measurements when equipped with Option 34 and/or Option 11. Option 34 provides for four-wire DC/DC, AC/DC and Ohms/DC ratios. Option 11 provides four ranges of AC reference input for AC/AC, AC/DC and Ohms/AC ratios. Due to hardware constraints, the 6000 will uprange or display "OL" whenever the signal becomes approximately ± 1.6 times the reference voltage.

3.3.10 Decibel (dB) Operation.

3.3.10.1 The 6000 DMM uses internal software to compute the value displayed when making dB measurements. The equation used for the dBm is: dBm = 10 Log (P1/.001) where P1 = (Voltage)2/Rref. The 6000 initializes with the reference resistor (Rref) set to the value of 600 ohms.

3.3.10.2 To perform dB measurements put the instrument into the dB mode by pressing the SHIFT and dB keys. Depress the F/R key as required to select the front input. Note that the display indicates dB. Apply the unknown voltage to the front panel input terminals and read the value in dB from the front panel display.

3.3.10.3 The simplest dB measurement is made by applying a signal to the front panel input terminals and displaying the voltage in terms of dB referenced to 1 millivolt expended in the standard 600 ohm resistor. Refer to Figure 3.8 (a graphic log chart of voltage vs dB). Note that the 600 ohm power value line (shown as a dotted line and marked "600 OHM POWER UP") crosses through the junction point of the 10 volt input voltage and 22 dB point on the chart. Thus the note, "reads 22.2 dB with 10 volts input".

3.3.10.4 The reference resistor value may also be programmed to values other than 600 ohms. This allows the Model 6000 to directly display dB measurements for other input impedances (eg: 50Ω, 300Ω, 1KΩ, 1MΩ). If, for example, measurements in dBV are to be made (0dBV = 1 volt into 1KΩ), then the reference resistor value may be set to 1KΩ. The table shown below illustrates the key sequence and the resultant display for this example (assume a 10 volt input).

Step	Key	Display
1	1 0 0 0	1000.
2	STORE	1000. (SFT)
3	dB	20.0 dB

3.3.10.5 The instrument may be used to make ratio measurements and present results in terms of decibels. For example, to measure the gain of an amplifier, connect the amplifier's input voltage to the rear panel input terminals of the Model 6000 DVM. Connect the amplifier output to the front panel input terminals of the instrument. Put the instrument in the ratio mode by pressing SHIFT and DC keys on the keyboard. The instrument will now display the ratio between the front and rear inputs in terms of decibels. If the output of the amplifier is less than the input of the amplifier the value displayed on the front panel of the Model 6000 will be preceded with the minus sign indicating a gain loss. Refer to the External Reference formula in Figure 3.8.

3.3.10.6 It should be noted that the dB function can be used in combination with other measurement functions such as the ratio measurement described above. Further the value of Rref does not affect the display result in a ratio operation because the instrument measures the ratio of the two input signals and then converts the ratio value to dB for display.

3.3.11 Math Function.

3.3.11.1 The Model 6000 includes in its repertoire a software mathmatical function which provides for offset and scaling of measurement values or ratio values. The formula used is (X-A) x B ÷ C where X stands for the measurement or ratio value displayed on the front panel. When the math function is selected, the instrument performs the equation on the displayed value (ie: it subtracts the value of constant A from the measurement, multiplies this by the constant B and divides the result by the constant C). The math function may be selected by pressing the [(X-A)B/C] key on the keyboard or by sending the appropriate command to the GPIB interface (reference Table 3.12).

3.3.11.2 When the instrument initializes, the constants A, B and C are set to values calculated to have no effect on the measurement value X. Constant A is set to zero, constant B is set to 1 and constant C is set to 1. Thus, it can be seen that if the equation with these constants were performed on any value the result would be the same as the original value of X.

3.3.11.3 To store the A, B and C constant values used in the math algorithm, enter the desired value through the keyboard and then press the store key followed by the key of the desired memory location. Repeat this procedure for each of the three memory locations. If not changed, the constants will remain at their initialized values. The memory locations may be individually cleared by pressing the Shift, Clear and memory location keys.

3.3.11.4 OFFSET.

3.3.11.4.1 The math function may be used to perform simple measurement offsets. In this mode R = X–A, where R is the displayed value, X is the measured value and A is the offset constant. Since the stored constant (A) may be either positive or negative, the offset may be either added or subtracted from the measurement (X).

3.3.11.5 SCALING.

3.3.11.5.1 The math function may also be used to perform scaling operations. As an example, the math function may be used to convert the 1 mV/°C output of the Racal-Dana Model T-10 Temperature Probe into Farenheit degrees. In this example the displayed reading would be equal to $\frac{(X-A)B}{C}$, where X is the measured value (in mV/°C), A is the constant "–.017778", B is the constant "9000" and C is the constant "5". The resulting display will represent the Probe temperature reading in °F.

3.3.12 Heirarchy of Operations.

3.3.12.1 Multiple operations, if selected, will occur in the order shown in Figure 3.9.

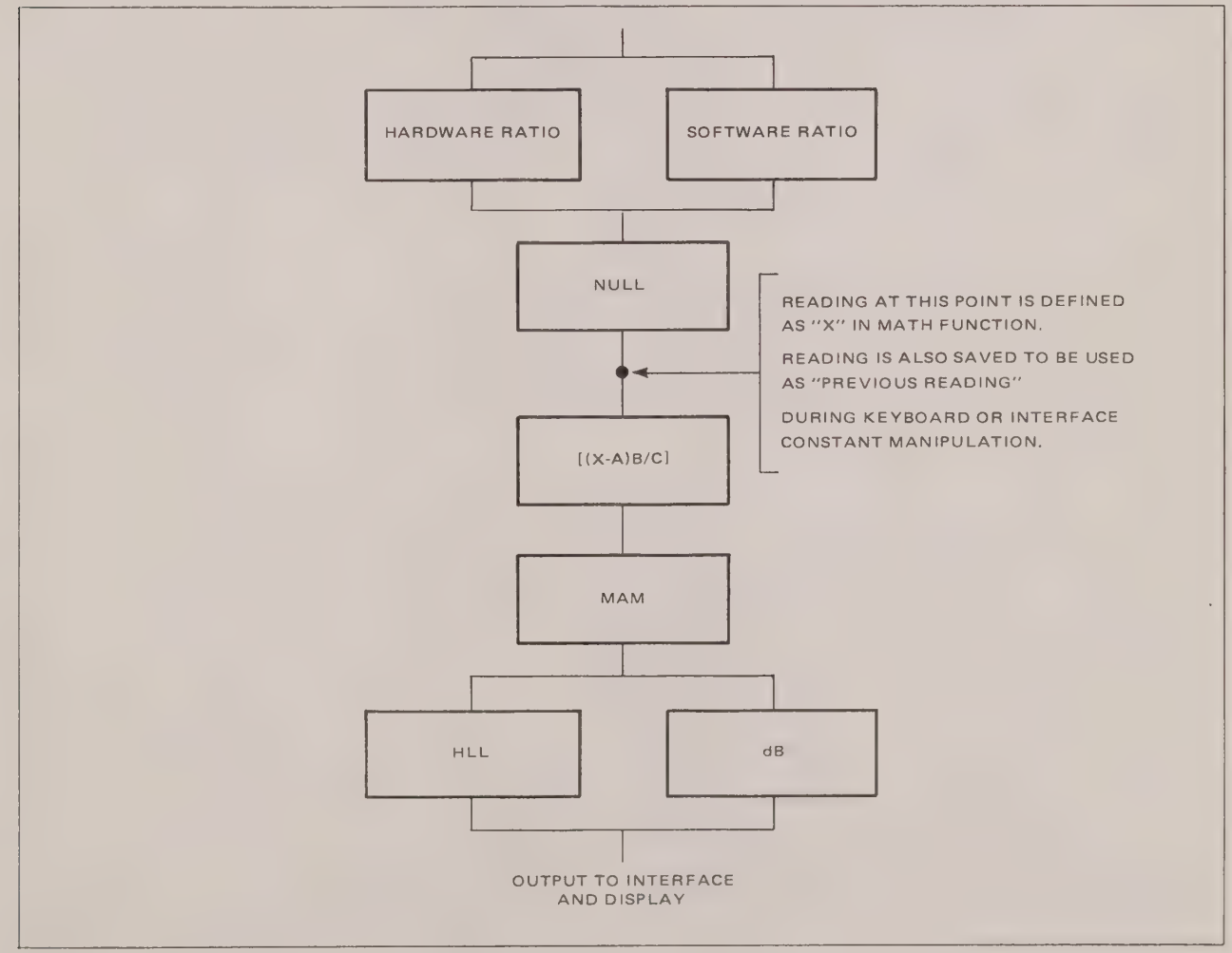


Figure 3.9 - Heirarchy of Operations

3.3.13 Error Messages.

3.3.13.1 Error messages and their descriptions are listed in Table 3.7.

Table 3.7 - Error Messages

Error Number	Description
0	Cannot calculate Log of zero
2	Attempted Auto-Cal when in 1000V signal or reference range
10	Improper Key sequence
11	Illegal # digits request
12	Divide by zero
13	Exponent cannot be displayed when in 6 1/2 digit mode
14	Display exponent beyond + 9
20	Required board missing from main analog section
21	Required board missing from CAL module
22	Signal RMS converter not installed
23	Reference RMS converter not installed
24	AC converter not installed
25	Ohms converter not installed
26	4-wire DC external reference not installed
29	Fast Digitizer not installed
30	RAM failure on computer board
31	DC or reference Non Vol number out of spec
32	Ohms Non Vol number out of spec
33	Non Vol will not write or Cal switch bad
34	Clock on Non Vol board not oscillating
35	Reading will not trigger on control logic board
36	No axis crossing detected from Integrator board
	Warning Auto-Cal reading taken during:
61	DC CAL 1 (Isolator/Digitizer - Positive Ref. Voltage)
62	DC CAL 2 (Attenuator - Positive Ref. Voltage)
63	DC CAL 3 (Isolator/Digitizer - Negative Ref. Voltage)
64	DC CAL 4 (Attenuator - Negative Ref. Voltage)
65	DC CAL 5 (10 Volt Range)
66	DC CAL 6 (1 Volt Range)
67	DC CAL 7 (100 mV Range)
68	DC CAL 8 (10 mV Range)
71	OH CAL 1 (10Ω Range)
72	OH CAL 2 (100Ω, 1KΩ Ranges)
73	OH CAL 3 (10KΩ - 100MΩ Ranges)
74	OH CAL 4 (Input Bias Current)
75	OH CAL 5 (Internal 10KΩ Resistor Standard)
76	OH CAL 6 (1Ω Range)

Table 3.7 - Error Messages continued

Error Number	Description
	Unable to Auto-Cal during:
81	DC CAL 1 (Isolator/Digitizer - Positive Ref. Voltage)
82	DC CAL 2 (Attenuator - Positive Ref. Voltage)
83	DC CAL 3 (Isolator/Digitizer - Negative Ref. Voltage)
84	DC CAL 4 (Attenuator - Negative Ref. Voltage)
85	DC CAL 5 (10 Volt Range)
86	DC CAL 6 (1 Volt Range)
87	DC CAL 7 (100 mV Range)
88	DC CAL 8 (10 mV Range)
91	OH CAL 1 (10Ω Range)
92	OH CAL 2 (100Ω, 1KΩ Ranges)
93	OH CAL 3 (10KΩ - 100MΩ Ranges)
94	OH CAL 4 (Input Bias Current)
95	OH CAL 5 (Internal 10KΩ Resistor Standard)
96	OH CAL 6 (1Ω Range)

3.4 SYSTEM OPERATION.

3.4.1 This subsection presents information on the operation of the 6000 in a system. Two programmable interfaces are available. An IEEE-488 interface allows the 6000 to be connected to controllers and instruments which are manufactured by a variety of companys around the world. A parallel BCD interface is designed for those customers who are presently using the Racal-Dana Model 5900 and would like to upgrade to the 6000. In order to maximize throughput during system operation, the front panel display is given a low priority by the 6000's microprocessor. Consequently, there may be times when the 6000's seven segment display becomes incorrect or unreadable. This is no cause for concern and will not affect the accuracy of data being outputted to the interface.

3.4.2 General Purpose Interface Bus.

3.4.2.1 The Interface Board provides for remote programming of all controls and the output of data from the 6000. Inputs and outputs for the option are made via a 24 pin connector located on the rear panel. The pin location, line identification, and operation of the option are in compliance with IEEE-STD-488-1975. The Interface Board provides interface capability with other instruments and with a controller also utilizing the "interface bus" structure. Connector contact assignments are shown in Figure 3.10. The IEEE-488-1975 subsets available in the Series 6000 are listed in Table 3.8.

3.4.2.2 By assigning a unique address to the 6000, it can be "called up" by the controller or another device on the bus without interfering with other units on the bus. Switches located on the rear panel of the 6000 permit the programming of the instrument address. The coding used for the address on the option board is ASCII (hexadecimal). Any one of 31 codes can be used for the address of an instrument, but a total of 15 is the maximum number of devices that can be used on one bus. The 6000 address can be displayed by first pressing the "Shift" key and then holding the "Local" key down.

3.4.3 GPIB Description.

3.4.3.1 Of the twenty-four lines available at the connector (shown in Figure 2.4) seven are grounds, one is a shield, and the remaining 16 lines are the signal lines. All of the signal lines are either input or output lines and have the following characteristics:

Logic Levels: 1 = Low = $\leq$ .8V 0 = Hi = $\geq$ 2.0V

Input Loading: Each input ~ two TTL loads

Output: The output is capable of driving 15 interface bus loads. It consists of an open collector driver and is capable of sinking 48 mA with a maximum voltage drop of 0.4 volts. See IEEE 488 Electrical Specifications.

3.4.3.2 The signal lines, as shown in Figure 3.10, consist of three functionally separate sets: Data, Handshake and Interface.

3.4.3.3 DATA.

3.4.3.3.1 The data lines consist of lines DI0-1 through DI0-8. These lines are the lines over which data flows between all instruments on the bus in bit parallel, byte serial form.

3.4.3.4 HANDSHAKE.

3.4.3.4.1 The transfer lines consist of: DAV (data valid), NDAC (not data accepted), and NRFD (not ready for data). These lines provide communication (between the instrument that is talking and the instruments that are listening) to synchronize the flow of information across the eight data lines. These lines derive their nomenclature from their meaning in the low or one state (eg: when NRFD is low the device is Not Ready For Data).

a. DAV. Signifies that valid information is available on the data lines.

b. NRFD. Signifies that the instrument is not ready to accept information.

c. NDAC. Signifies that the information is not accepted by the acceptor.

3.4.3.5 INTERFACE.

3.4.3.5.1 The five interface lines coordinate the flow of information on the bus.

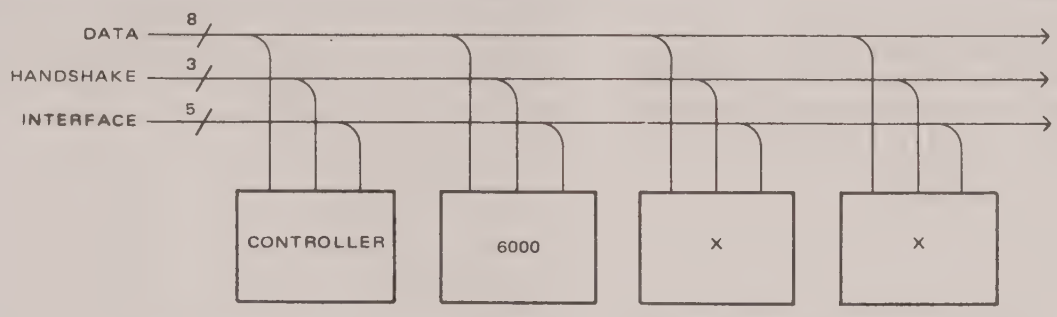
a. IFC. Places the Model 6000 in the IDLE state. (Untalk, Unlisten).

b. ATN. Indicates the nature of information on data lines during a handshake transfer sequence. Low indicates data lines carry interface commands; high indicates that the data lines carry data.

c. REN. Arms instrument to select Remote operation. (Low for Remote.)

d. SRQ. Service request signal line. Signals the controller that a peripheral or bus member wants attention for such purposes as transmitting measurement, status or condition information to the bus controller.

e. EOI. End or Identify signal. Used for two purposes: (1) to signify the end of a message and (2) to signal bus peripherals to set the I/O bit assigned for parallel poll identification process.



PIN			PIN	
1	DIO-1 Data In/Out Bit 1 (LSB)	DATA LINES ARE USED TO TRANSFER DATA FROM ONE INSTRUMENT TO ANOTHER	12	SHIELD
2	DIO-2 Data In/Out Bit 2		18	GND
3	DIO-3 Data In/Out Bit 3		19	GND
4	DIO-4 Data In/Out Bit 4		20	GND
13	DIO-5 Data In/Out Bit 5		21	GND
14	DIO-6 Date In/Out Bit 6		22	GND
15	DIO-7 Data In/Out Bit 7		23	GND
16	DIO-8 Data In/Out Bit 8		24	LOGIC GND
6	DAV (DATA VALID)	HANDSHAKE LINES OPERATE IN A PROPER TIME SEQUENCE FOR COMPLETE COMMUNICATION BETWEEN INSTRUMENTS	25	NOT USED
7	NRFD (NOT READY FOR DATA)			
8	NDAC (NOT DATA ACCEPTED)			
5	EOI (END OR IDENTIFY)	INTERFACE LINES ARE USED TO PROVIDE AN ORDERLY FLOW OF INFORMATION BE-TWEEN UNITS		
9	IFC (INTERFACE CLEAR)			
10	SRQ (SERVICE REQUEST)			
11	ATN (ATTENTION)			
17	REN (REMOTE ENABLE)			

Figure 3.10 - Interface Signal Pin Assignments

Table 3.8 -
IEEE 488 1975 Standard Interface Subset Capability of 6000 DMM

Subset Mnemonic	Function	Capability
SH1	Source Handshake	Complete
AH1	Acceptor Handshake	Complete
T5	Talker	Complete
TE0	Extended Talker	None
L4	Listener	All except listen only
LE0	Extended Listener	None
SR1	Service Request	Complete
RL1	Remote/Local	Complete
PP0	Parallel Poll	None
DC1	Device Clear	Complete
DT1	Device Trigger	Complete
C0	Controller	None
E1	Open collector bus drivers	–

3.4.4 Handshake.

3.4.4.1 The handshake is the process by which each data byte is transferred from the source to the acceptor. Figure 3.11 illustrates the sequential relationship between the DAV, NRFD, and NDAC lines (used to transfer data bytes). Figure 3.12 illustrates the handshake flow chart.

3.4.5 Address Assignment.

3.4.5.1 When the Series 6000 is used as a system instrument it must be assigned an address as a bus member. The instrument is equipped with an address switch located on the rear panel which enables the user to assign it one of 31 decimal addresses. The decimal addresses available are the numbers 00 through 30.

3.4.5.2 Table 3.9 contains all of the information required for setting the instrument address switch and for determining the talk and listen address codes used in programming the controller.

3.4.5.3 Refer to Table 3.9 and note that the right hand column shows the decimal addresses available for assignment to the 6000. The column titled Address Switch Setting illustrates the positions of the switches for each decimal address. To set the address on the instrument at the desired decimal address, refer to Table 3.9, and set the switches on the address switch to the pattern shown in the Address Switch column of the table.

3.4.5.4 As an aid in setting the address switches, the decimal address may be displayed on the 6000 readout by first pressing the "Shift" key and then holding the "Local" key down. The address switches may then be set until the desired address appears on the display.

3.4.5.5 Once the instrument has been assigned an address, and the address switch has been set, the controller may address the instrument as a talker or as a listener by transmitting the appropriate ASCII character on the data lines. The Data Lines column shows the 7 bit binary code required for each talk and listen address assigned to the instrument. These are the codes the controller must transmit to establish the talker/listener condition of the 6000. Note that there are two address codes used for each decimal address. Each of these address codes constitutes a different ASCII character. For example, if it is desired to use the decimal address 02, the address switch on the rear panel of the instrument is set to the pattern shown in Table 3.9. As shown in the table, the talk address is the ASCII character " and the listen address is the ASCII character B. Note that the only difference in the binary code in each case is the state of data lines D6 and D7.

3.4.5.6 Table 3.9 illustrates the data line code in binary form for each decimal address. Again, using the example for decimal address 02, note that bits D1 through D5 are the same for both talk and listen address and that the only difference is in bits D6 and D7.

3.4.6 Bus Operation Sequence.

3.4.6.1 The transmission of programming instructions to the Series 6000 and the subsequent transmission of measurement data to the controller are accomplished by transmitting programming instructions as outlined in the bus operation sequence in Table 3.10. Table 3.10 and the accompanying timing chart (Figure 3.11) illustrate the sequence of the transmission of device dependent messages to the 6000 which cause it to measure the voltage of a measurement signal applied to the input and then transmit the resultant measurement data to the controller via the interface bus.

3.4.6.2 Note that the left hand column of Table 3.10 contains line numbers. These are used for reference purposes throughout the following description of the bus operation sequence. The column titled Handshake Lines indicates the high/low condition of the handshake lines at various points throughout the two-way transmission of information. In a similar fashion the columns titled Interface Lines and Data Lines contain entries reflecting the state of the interface lines and data lines during operation. The column titled Meaning or Function contains entries explaining the purpose of each operational step during the data transfer.

3.4.6.3 A timing chart is included to illustrate the condition of each individual bus line at each stage of the data transfer operation. Note that the timing chart includes numbers adjacent to each level change. These numbers refer to the individual line entries of the table.

3.4.6.4 The measurement operation used in Table 3.10 is a simple voltage measurement. The measurement parameters are as follows: Function DC volts, Range 10 volts, Trigger continuous. Note that the measurement parameters are shown in the meaning or function column of the table in lines 17 through 22 and that the program string required to perform this measurement is F1R5T1. The program string will include a carriage return and line feed, but in this case this command is automatically transmitted by the Hewlett Packard 9825.

3.4.6.5 For purposes of this example it is assumed that the Model 6000 has been assigned the decimal address 02 and that the controller is a Hewlett Packard 9825 calculator with a talk address U. It is further assumed that both the controller and the Model 6000 are system connected, turned on and operational.

3.4.6.6 Table 3.10 shows the sequence of bus operation. Lines 1 through 13 show the detailed operation of the bus for one handshake cycle (ie: the transmission of one ASCII character as a bus message). Lines 14 through 44 do not indicate the detail for each handshake cycle; they indicate only the transmission of the characters required for the programming commands and the subsequent transmission of the data by the Series 6000. Each transmission by the controller or the DMM, shown in lines 14 through 44, requires the handshake cycle illustrated by line entries 1 through 13 of the table.

3.4.6.7 Refer to Table 3.10, line 1, and note that the first operation performed is the setting of the Remote Enable (REN) line to the low state. As explained in the table, this operation arms the bus members to go to the remote mode. The controller then transmits the interface clear (IFC) signal which stops bus activity and the attention (ATN) line is set low indicating that the next data byte placed on the bus by the controller will be a Bus Message. Note in the timing chart that when the ATN line is set low (3) that the 6000 responds by setting the NRFD line high (4). This response by the 6000 indicates that it is now ready to accept data.

3.4.6.8 When the DMM transmits the ready for data signal by setting the NRFD line high (line 4 of Table 3.10) the controller puts the bus message UNL on the data lines. As shown in line 5 of the table this is the ASCII character ?. The unlisten message is a universal message understood by all bus members as the command "unlisten". Having placed the data character on the lines, the controller now says the data is valid by setting the DAV line low (6). The DMM then says "I'm going to accept the data now on the data lines; don't change the data lines". The DMM then reads the data lines (8) and acknowledges acceptance of the data by setting the NDAC line high (9). The controller then removes the data valid signal (10), removes or changes data (11) and the DMM removes the data accepted signal from the bus (12).

3.4.6.9 At this point, one ASCII character has been transmitted by the controller to the DMM and the DMM is now ready to accept a new data byte. It indicates this (13) by setting the NRFD line high. The controller now puts the next character on the data line and the handshake cycle for the transfer of the character is repeated. The next character transmitted by the controller is the ASCII character U which is the talk address of the Hewlett-Packard 9825 calculator. As indicated in Table 3.10, by transmitting this character the calculator is making itself a talker. The next character transmitted is the quotation mark which is the listen address of the 6000 DMM when it has been assigned the decimal address 02.

3.4.6.10 Lines 16 through 24 of the table illustrate the sequence of transmission of the program string which instructs the DMM to make the DC voltage measurement. Lines 26 and 29 of the table indicate the end of transmission with the characters CR (carriage return) and LF (line feed). Note that at line 16 of the table the controller sets the ATN line high indicating that the program string to follow in lines 17 through 24 are device dependent messages.

3.4.6.11 Having transmitted the program string of device dependent messages to the DMM, the controller then sets the ATN line low which indicates that the characters to follow in lines 26 through 28 are bus messages. These bus messages change the talker/listener relationship of the controller and DMM; the DMM is made a talker and the controller becomes a listener.

3.4.6.12 Lines 30 through 44 illustrate the sequence of the transmission of data by the DMM. The handshake sequence is the same when the DMM is transmitting data as that outlined in lines 1 through 13 of the table, except that the DMM is controlling the handshake lines.

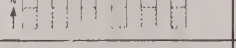
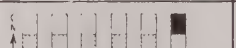
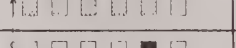
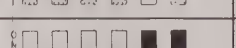
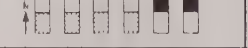
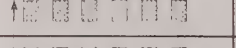
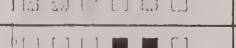
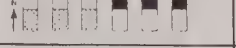
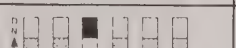
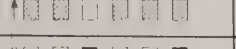
3.4.6.13 Upon completion of the data transmission, the Series 6000 transmits a carriage return (CR) and line feed (LF) to indicate the end of the data transmission.

3.4.7 Interface Message Repertoire.

3.4.7.1 The Series 6000 DMM is equipped with a standard GPIB interface which conforms to the specifications contained in IEEE-488-1975. The specification includes the definition of multi-line interface messages and this definition divides the messages into two groups; the primary command group and the secondary command group. The 6000 includes none of the secondary command group in its interface message repertoire.

3.4.7.2 The primary command group of interface messages is further broken down into four lower categories: (1) the listen address group, (2) the talk address group, (3) the universal command group and (4) the addressed command group. The 6000 is designed to include in its interface message repertoire 31 listen addresses and 31 talk addresses.

Table 3.9 - Model 6000 Interface Addressing

ASCII CHARACTERS		DATA LINES							ADDRESS* SWITCH SETTING	DECIMAL ADDRESS
		D_7	D_6	D_5	D_4	D_3	D_2	D_1		
TALK	LISTEN	TALK	LISTEN	ADDRESS					TALK ONLY A5 A4 A3 A2 A1	
				16	8	4	2	1		
	SP	0	1	0	0	0	0	0		00
@		1	0	0	0	0	0	0		
	!	0	1	0	0	0	0	1		01
A		1	0	0	0	0	0	1		
	"	0	1	0	0	0	1	0		02
B		1	0	0	0	0	1	0		
	#	0	1	0	0	0	1	1		03
C		1	0	0	0	0	1	1		
	$	0	1	0	0	1	0	0		04
D		1	0	0	0	1	0	0		
	%	0	1	0	0	1	0	1		05
E		1	0	0	0	1	0	1		
	&	0	1	0	0	1	1	0		06
F		1	0	0	0	1	1	0		
	' (APOSTROPHE)	0	1	0	0	1	1	1		07
G		1	0	0	0	1	1	1		
	(	0	1	0	1	0	0	0		08
H		1	0	0	1	0	0	0		
	)	0	1	0	1	0	0	1		09
I		1	0	0	1	0	0	1		
	*	0	1	0	1	0	1	0		10
J		1	0	0	1	0	1	0		
	+	0	1	0	1	0	1	1		11
K		1	0	0	1	0	1	1		
	,	0	1	0	1	1	0	0		12
L		1	0	0	1	1	0	0		
	-	0	1	0	1	1	0	1		13
M		1	0	0	1	1	0	1		
	.	0	1	0	1	1	1	0		14
N		1	0	0	1	1	1	0		
	/	0	1	0	1	1	1	1		15
O		1	0	0	1	1	1	1		

*Switches in the logical "1" position are shown in black. Switches in the logical "0" position are shown in grey.

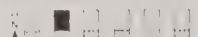
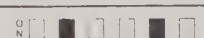
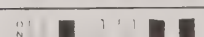
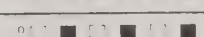
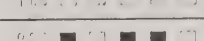
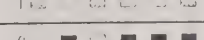
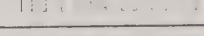
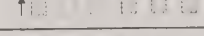
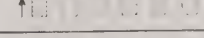
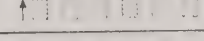
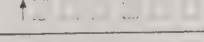
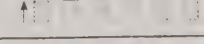
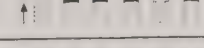
DATA LINES							ADDRESS* SWITCH SETTING	DECIMAL ADDRESS
D_7	D_6	D_5	D_4	D_3	D_2	D_1	TALK ONLY 1 / 0 — A5 A4 A3 A2 A1	
TALK	LISTEN	ADDRESS						
		16	8	4	2	1		
0	1	1	0	0	0	0		16
1	0	1	0	0	0	0		
0	1	1	0	0	0	1		17
1	0	1	0	0	0	1		
0	1	1	0	0	1	0		18
1	0	1	0	0	1	0		
0	1	1	0	0	1	1		19
1	0	1	0	0	1	1		
0	1	1	0	1	0	0		20
1	0	1	0	1	0	0		
0	1	1	0	1	0	1		21
1	0	1	0	1	0	1		
0	1	1	0	1	1	0		22
1	0	1	0	1	1	0		
0	1	1	0	1	1	1		23
1	0	1	0	1	1	1		
0	1	1	1	0	0	0		24
1	0	1	1	0	0	0		
0	1	1	1	0	0	1		25
1	0	1	1	0	0	1		
0	1	1	1	0	1	0		26
1	0	1	1	0	1	0		
0	1	1	1	0	1	1		27
1	0	1	1	0	1	1		
0	1	1	1	1	0	0		28
1	0	1	1	1	0	0		
0	1	1	1	1	0	1		29
1	0	1	1	1	0	1		
0	1	1	1	1	1	0		30
1	0	1	1	1	1	0		
ILLEGAL							NONE	31

Table 3.10 - Bus Operation Sequence

	HANDSHAKE LINES	BUS LINES	DATA LINES	MEANING OR FUNCTION
1		REN Lo		Arms bus peripherals to go to remote mode.
2		IFC		Stops activity on the bus.
3		ATN Lo		Signifies that data byte will be a "Bus Message".
4	NRFD Hi			DMM says ready for data.
5			?	UNL (Unlisten) message (ASCII character ?) on data bus by controller means "all bus peripherals unlisten".
6	DAV Lo			Controller says data on bus is valid.
7	NRFD Lo			DMM says its not ready for new data; do not change data lines while DMM is accepting data.
8				DMM reads data lines.
9	NDAC Hi			DMM says it has read data.
10	DAV Hi		?	Controller says data no longer valid.
11	NDAC Lo			DMM removes data accepted flag.
12	NRFD Hi			DMM says it's ready for next data byte.
13				Controller removes or changes data on bus.
14			U	"I talk", controller becomes talker (HP9825 talker address).
15			"	"You listen", addressed peripheral becomes listener (In this case it is the 6000 DMM set to decimal address 02; see table 3.9).
16		ATN Hi		Signifies that data byte will be a "Device Dependent Message" as opposed to an "Interface Message".
17			F	Function
18			1	DC Volts
19			R	Range
20			5	10 Volts
21			T	Trigger
22			1	Continuous
23			CR	End of transmission by HP9825.
24			LF	
25		ATN Lo		Byte to follow is a Bus Message.
26			?	UNL (unlisten) bus message.
27			B	"You talk", 6000 talk address (02).
28			5	"I listen", HP9825 listen address.
29		ATN Hi		Message to be transmitted by DMM is Data.
30			+	} Measurement data transmitted by DMM
31			1	
32			.	
33			0	
34			2	
35			5	
36			4	
37			6	
38			8	
39			E	Exponent Indicator means X 10^{01}
40			+	Sign of exponent.
41			0	} Exponent. Here it indicates 10^{10}.
42			1	
43			CR	} End of 6000 data message.
44			LF	

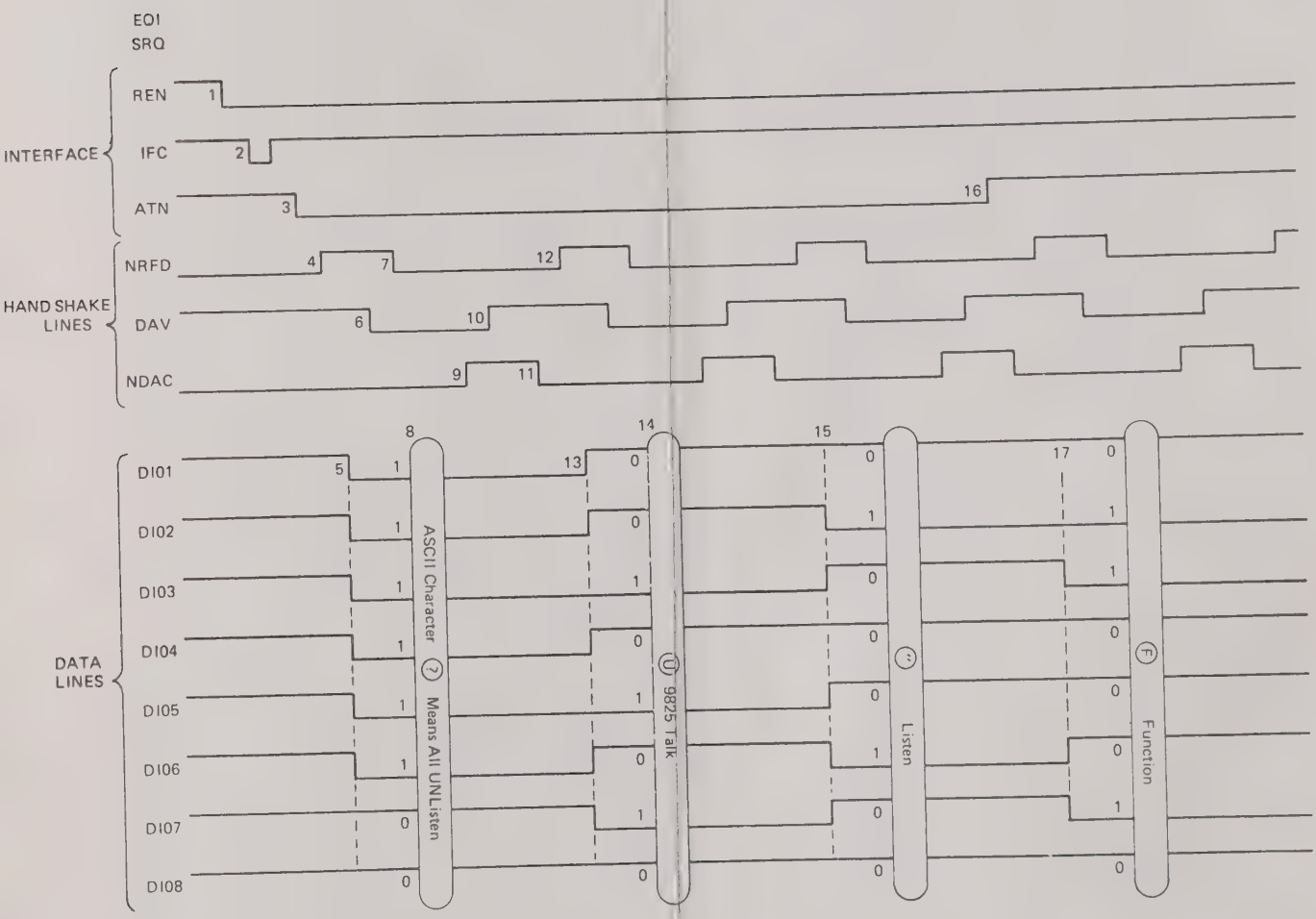


Figure 3.11 - Interface Timing

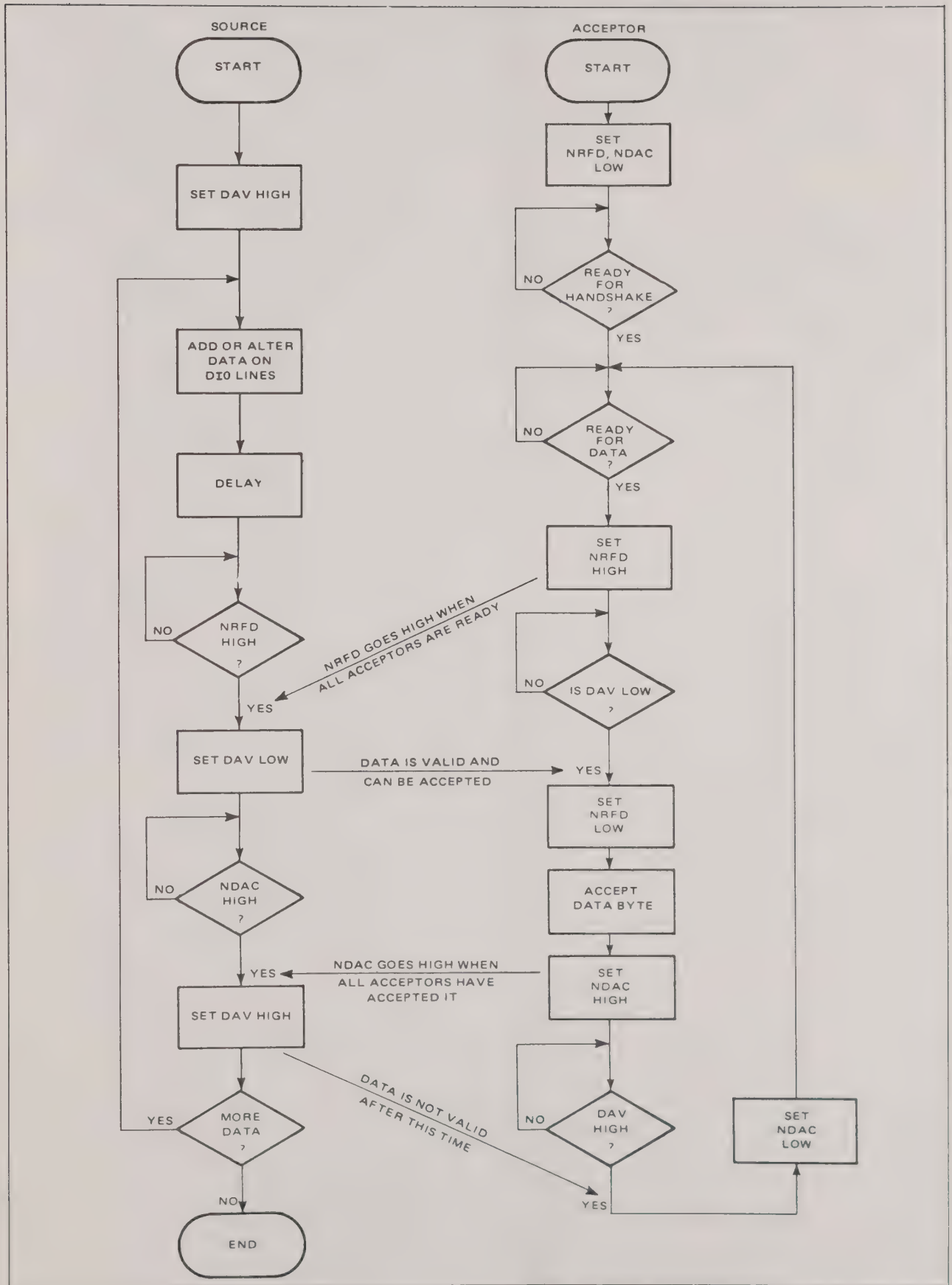


Figure 3.12 - Handshake Flow Chart

Table 3.11 - Interface Messages Used With Model 6000 DMM

Message	Meaning	HEX CODE	Decimal Equiv.	DATA LINE CODE						
				7	6	5	4	3	2	1
GTL	Go To Local	01	1	0	0	0	0	0	0	1
SDC *	Selected Device Clear	04	4	0	0	0	0	1	0	0
GET *	Group Execute Trigger	08	8	0	0	0	1	0	0	0
LLO	Local Lock Out	11	17	0	0	1	0	0	0	1
DCL	Device Clear	14	20	0	0	1	0	1	0	0
SPE	Serial Poll Enable	18	24	0	0	1	1	0	0	0
SPD	Serial Poll Disable	19	25	0	0	1	1	0	0	1
UNL	Unlisten	3F	63	0	1	1	1	1	1	1
UNT	Untalk	5F	95	1	0	1	1	1	1	1

*Instrument will ignore message unless it is a listener

The listen and talk addresses to which the 6000 may be set are listed in Table 3.9.

3.4.7.3 The interface messages to which the 6000 DMM is designed to respond are listed in Table 3.11 along with their decimal equivalents, hex equivalents, meanings and data line codes. The function of the 6000 in response to each of these commands is described in the following paragraphs.

3.4.7.4 GO TO LOCAL (GTL).

3.4.7.4.1 As shown in Table 3.11, the GTL command means go to local and the decimal and hex equivalent are both 01. Upon receipt of this interface message, the 6000, if previously programmed for remote, will return to its local operational state. This means that the instrument will then perform the function according to the settings of the front panel controls on the instrument until such time as it returns to remote control.

3.4.7.5 SELECTED DEVICE CLEAR (SDC).

3.4.7.5.1 Upon receipt of the SDC command, the 6000 will go to the home state. The decimal and hex equivalent are both 04.

3.4.7.6 GROUP EXECUTE TRIGGER (GET).

3.4.7.6.1 As shown in Table 3.11, the decimal and hex equivalents of the GET command are both 08. Upon receipt of the GET interface message, the 6000 will trigger a reading if it had previously been placed in the HOLD mode. The group execute trigger command is used to trigger the simultaneous execution of a number of functions by a number of bus members at the same time. To use this command, two or more bus members are programmed to perform a function on receiving the GET interface message or a trigger command. Subsequently, the controller will transmit the GET command and all bus members previously programmed will begin execution on receipt of the command.

3.4.7.7 LOCAL LOCK OUT (LLO).

3.4.7.7.1 The Series 6000 is armed to go to remote operation when the remote enable (REN) bus management line is set to the 1 (low) state by the controller. The 6000 may be brought back into local control by pressing the "Shift" key and then the "Local" key on the keyboard. If, however, the 6000 receives an LLO (Hex 11 or decimal 17) command while in remote operation, it may not be brought back into local control through keyboard operation.

3.4.7.8 DEVICE CLEAR (DCL).

3.4.7.8.1 The decimal equivalent of the DCL command (as shown in Table 3.11) is 20, and the hex equivalent is 14. This command is identical in operation to the SDC command except that it is a universal command and will not necessarily include the address of the 6000. When this command is transmitted on the bus, all devices on the bus which respond to the DCL will clear.

3.4.7.9 SERIAL POLL ENABLE (SPE).

3.4.7.9.1 As shown in Table 3.11, the decimal equivalent of this interface command is 24; the hex equivalent is 18. The function of this command is to cause all bus members responding to the SPE command to ready their status word. Thus, when a bus member has transmitted a service request (SRQ), the bus controller can transmit the serial poll enable command, sequentially command each bus member to transmit its status byte and thus identify the bus member requesting attention. Upon receipt of the SPE interface message, the 6000 immediately prepares to respond to a status request from the controller. If the 6000 has previously transmitted an SRQ, it will set bit 7 of the status byte to 1. The serial poll allows a bus member to set the service request line to the 1 state, thus indicating to the controller that it wants attention. The controller may then sequentially interrogate each bus member to determine which one has requested service and the purpose of the request. The meanings of the bits in the status bytes are shown in Figure 3.13.

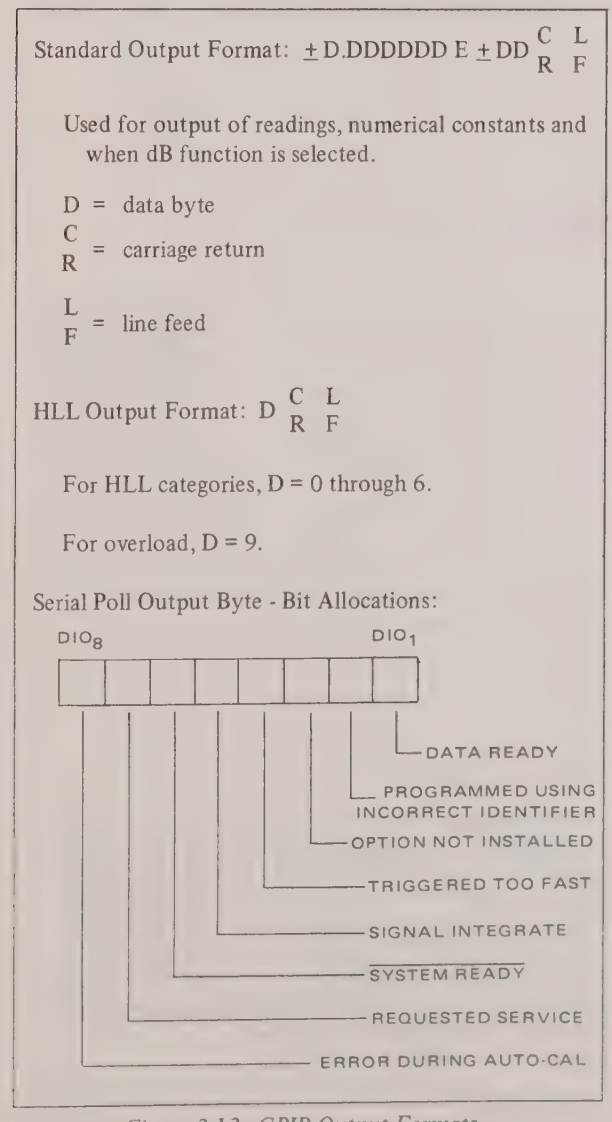

Standard Output Format: ±D.DDDDDD E ±DD CR LF
Used for output of readings, numerical constants and when dB function is selected.
D = data byte
CR = carriage return
LF = line feed
HLL Output Format: D CR LF
For HLL categories, D = 0 through 6.
For overload, D = 9.
Serial Poll Output Byte - Bit Allocations:
DIO8
DIO1
DATA READY
PROGRAMMED USING INCORRECT IDENTIFIER
OPTION NOT INSTALLED
TRIGGERED TOO FAST
SIGNAL INTEGRATE
SYSTEM READY
REQUESTED SERVICE
ERROR DURING AUTO-CAL

Figure 3.13 - GPIB Output Formats

3.4.7.10 SERIAL POLL DISABLE (SPD).

3.4.7.10.1 As shown in Table 3.11 the decimal equivalent to the SPD command is 25; the hex equivalent is 19. The function of this command is to return the bus members to their original states after the serial poll transaction has been completed.

3.4.7.11 UNLISTEN (UNL).

3.4.7.11.1 As shown in Table 3.11 the decimal equivalent of this command is 63; the hex equivalent is 3F. This command is also a universal interface message understood by all members of the bus as a command to go to the unlisten state. When this command is transmitted, all bus members previously in the listen state will return to the unlisten state.

3.4.8 Device Dependent Messages.

3.4.8.1 The messages which control the operation of the Series 6000 DMM when in system operation are referred to as device dependent messages. These messages are simply combinations of ASCII characters which the instrument recognizes as specific instructions. To program the instrument for a specific operation, the operator programs the controller to transmit a sequence of these messages (referred to as a program string). The program string is variable in length and has no fixed format. Individual commands may be transmitted in any order and require no delimiters or spacing for the instrument to understand. A terminator character(s) should be sent as the last character in each program string. Acceptable terminators are CR (Carriage Return), LF (Line Feed), or both. Most controllers will add these to the program string automatically. Alphabetic characters may be either upper or lower case.

3.4.8.2 The device dependent messages are listed in Table 3.12 along with the 6000 operation and any special notes that apply. The device dependent messages applicable to the Series 6000 are divided into subcategories of Function Commands and Range Commands. In general, the various commands cause the instrument to perform the same functions as the front panel controls. There are special cases however, where there are extra functions available under remote control which are not available in the bench operation mode. Further, there are some special situations re-

quiring special attention to the operation sequence used with the 6000.

3.4.8.3 To assemble a program string, first list the requirements of the program, and then select the appropriate program codes from Table 3.12. Table 3.10 shows a program string listing for a typical measurement procedure.

3.4.9 Function Commands.

3.4.9.1 Function commands are available to program the instrument to perform any operation which may be commanded through use of front panel keyboard controls. Note that in Table 3.12 the 6000 Operation column lists the functions available on the instrument and that the Program Code column shows the ASCII characters required to program the instrument for each of these functions. To program a function the controller need only transmit the ASCII characters required for the desired function (eg: to program the measurement function DC volts, the controller simply transmits the two ASCII characters F and 1 over the bus to the Model 6000).

3.4.10 Range Commands.

3.4.10.1 Ten individual range commands are available to the controller; one to command the autorange and nine additional commands for selecting specific ranges for the instrument. Note that the R1 and R2 commands both call for the 10 millivolt range when used in a program string for voltage measurements. If the instrument is commanded to go to the 10 millivolt range with the use of an R1 command it will uprange automatically to 100 millivolts if overload occurs. If the instrument is commanded to go to the 10 millivolt range with an R2 command it will remain on the 10 millivolt range even if an overload occurs. Note that the commands R1 through R9 all serve dual purposes; they command ranges for voltage measurements and for resistance measurements.

3.4.11 Trigger Commands.

3.4.11.1 Trigger commands T0 through T5 control the beginning of a measurement cycle of the series 6000.

3.4.11.2 INTERNAL AND EXTERNAL TRIGGER.

3.4.11.2.1 When the T1 command is transmitted, the instrument operates on the internal trigger on its normal measurement timing cycle (see Figure 3.14). When the T2 command is transmitted, the instrument must be triggered by an external signal inputted through a BNC connector on the rear panel of the instrument.

3.4.11.3 HOLD MODE.

3.4.11.3.1 When the T3 command is transmitted, the instrument is put in the "Hold" state and will stay there until it is triggered either from the front panel or from the GPIB. Trigger commands from the GPIB can be either a T0 command or a Group Execute Trigger. Trigger commands are given from the keyboard by pressing (shift) hold when the machine is in local control.

3.4.11.4 When transmitting a T0 command or Group execute trigger to the 6000, the user may find that once in a great while the 6000 'rejects' the trigger command and issues an SRQ to the controller. Reading the serial poll status byte will then indicate that the 6000 has been triggered too fast. If this occurs, the controller can correct the situation by waiting approximately 10 milliseconds and then re-issuing the T0 or G.E.T. command.

3.4.11.5 TIMEOUT COMMANDS.

3.4.11.5.1 Upon receipt of the T4 program code the instrument goes into the External Trigger mode and must be triggered by an external signal connected to the rear panel BNC connector. After being triggered via the rear panel BNC, the 6000 executes a timeout which allows time for analog signals to settle. The timeout will vary, depending upon which functions and ranges are selected, before triggering a single reading. When program code T5 is transmitted, the instrument goes into the "Hold" mode described above except that its measurement cycle is again affected by the timeouts applicable to each function and range.

3.4.12 Integration Time Commands.

3.4.12.1 The measurement accuracy of the 6000 is directly proportional to the signal integration time (ie: the longer the integration time, the more accurate the measurement). If the measurement time is available, more accuracy may be obtained by programming the longer integration period. In situations where speed is required, the shorter integration time may be programmed at some sacrifice in measurement accuracy, see Figure 3.20. The program code I0 calls for the Fast Analog-to-Digital (Fast A/D) operating mode. This mode is useable in internal trigger and external trigger modes only and, in this mode of operation, the DMM makes repeated high speed measurements and transmits the information over the GPIB. Integration time commands I1 through I5, refer to Table 3.12, call for the specific integration times shown in the 6000 Operation column of the table. Note that the Special Notes column of the table indicates the number of digits displayed for each selected integration time.

3.4.13 Null Commands.

3.4.13.1 Program codes N0 through N3 call for the Null functions. The N1 program code enables the Null function. Upon receipt of N1 from the interface, a flag is set in memory which signals the Computer board to subtract the Null constant from future readings. The N2 program code allows for the storage of Null constants. Upon receipt of the N2 command, the previous reading is stored into memory

for use as the Null constant. The N3 program code causes the DMM to transmit the Null constant to the controller.

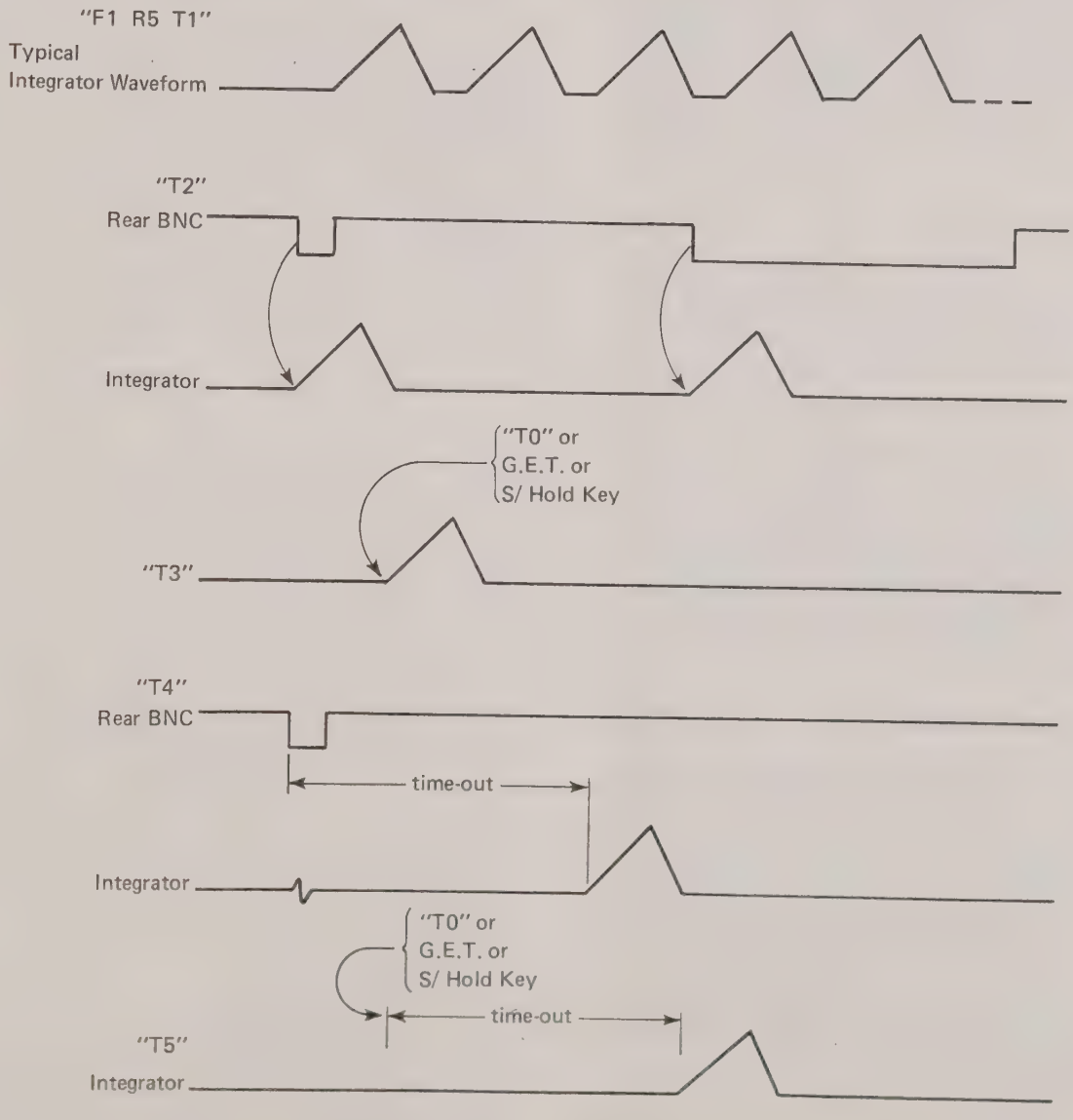
3.4.13.2 The N1N2 program string accomplishes the same operation as selection of the "Shift" and "Null" keys on the keyboard. Program code N0 disables the Null function but does not change the Null constant.

3.4.14 Display Commands.

3.4.14.1 The display of measurements takes extra time in the normal measurement cycle. This time may be saved in remote operation by disabling the display feature of the 6000. To disable the numeric display, the controller need only transmit the P0 program code. This reduces the internal measurement cycle time by 3 milliseconds, thereby allowing faster read rates. To restore the front panel display, the controller transmits the program code P1. When in the I0 mode, the display should be disabled if high read rates are desired.

3.4.15 Interrupt Commands.

3.4.15.1 Commands may be transmitted by the controller to instruct the 6000 as to the transmission of SRQ signals on the GPIB. When the controller transmits the D1 code, the Series 6000 indicates the completion of each reading by sending a SRQ. If the D0 code is received, no SRQ will be sent upon completion of a reading.



Note: G.E.T. is an abbreviation for the GPIB command "Group Execute Trigger"

See Table 3.28.

Figure 3.14 - Model 6000 DMM Trigger Command Timing

3.4.16 Hi-Low Limit Commands.

3.4.16.1 The GPIB commanded Hi-Low Limit feature of the Series 6000 operates in a similar fashion to the manual or bench mode. The enabling and disabling of the HLL function is controlled by transmission of the H1 and H0 program codes respectively. In a manner similar to manual operation, the controller can enter the Hi-Low Limit constants in the HLL locations 1 thru 6 by transmitting the storage location program codes H2 through H7 respectively. For example, to store the constant 1.5 in HLL constant location 1 the controller would transmit the constant 1.5 followed by the command H2. A similar sequence would be used to store the other HLL constants 2 thru 6 in the other locations. The program code H8 is unique to remote operation in that it calls for the retrieval from storage and transmission via GPIB of the program constants. When program code H8 is transmitted to the Model 6000 DVM the instrument retrieves the HLL constants stored in location 6 and transmits it first, followed by the remaining constants in reverse order as noted in the special notes column of the table. When using the H6 command, it should be the last command in the program string. The program code H9 initializes all six limits by setting them to ± 9.99E9.

3.4.17 Filter Commands.

3.4.17.1 Control of the filter in the remote mode is the same as manual control of the filter except that the controller transmits the program code commands J0 and J1 (as shown in Table 3.12).

3.4.18 Front/Rear Input Commands.

3.4.18.1 Selection of the Front/Rear input status is performed by transmitting the program code V0 to select the front input terminals of the instrument, or by transmitting program code V1 to select the rear input terminals.

3.4.19 External Reference Function Commands.

3.4.19.1 External reference function commands are used to select the reference used by the digital multimeter in making measurements. The controller may select the normal internal reference or an external ratio reference which may be applied to the input terminals or to the external reference connector located on the rear panel. Transmission of the X0 or X4 program codes by the controller causes the instrument to use the internal reference for all measurements. When using the instrument in the software ratio mode (DC reference), the input signal is applied to the selected input terminals as indicated by the RI lamp on the front panel. The reference is applied to the deselected input terminals, and the controller transmits the program code X1. For further explanation of input terminal selection refer to paragraph 3.3.9.4.

3.4.19.2 When using an AC reference voltage in the software ratio mode, the reference voltage is applied to the deselected input terminals and the input signal is applied to the selected input terminals. The controller then transmits program code X2 for AC coupled software ratio measurements.

3.4.19.3 It is possible to make software ratio measurements using a ratio reference voltage which is a DC voltage containing an AC component. The ratio reference voltage is applied to the deselected input terminals and the controller transmits program code X3. In this case the deselected terminals are DC coupled to the input of the instrument.

3.4.19.4 When using the instrument for hardware ratio measurements, the measurement signal is applied to the input terminals and the ratio reference voltage is applied to the connector marked EXT REF on the rear panel of the instrument. In this case, the reference voltage applied to the external reference connector is substituted for the internal reference and the program code transmitted by the controller is X5. In a similar fashion, an AC ratio reference voltage may be applied to the external reference connector. In this case the controller must transmit the program code X6.

3.4.19.5 The ratio reference voltage used with the hardware ratio mode of operation may be a DC voltage containing an AC component. In this case it is connected to the rear EXT REF connector and the program code transmitted by the controller is X7.

3.4.20 External Reference Range Commands.

3.4.20.1 There are six ranges for external reference voltages applied to the external reference connector on the rear panel of the instrument. These are the 10 millivolt through 1000 volt ranges listed in Table 3.12 under the 6000 Operation column. When using an external reference voltage in the remote mode, the controller must transmit the appropriate program code Y2 through Y7 to select the correct range for the external reference signal.

3.4.21 Min-Avg-Max Commands.

3.4.21.1 The Min-Avg-Max (MAM) commands used in remote operation allow operation of the instrument in exactly the same fashion as the MAM modes under manual operation. The program codes M0 through M6 listed in Table 3.12 are the equivalent of the keyboard controls used to operate the MAM feature of the instrument. To

perform a MAM measurement the controller must transmit a series of program strings as outlined in the following paragraph.

3.4.21.2 To initiate the MAM cycle, the controller must transmit the program code M6. This is equivalent of depressing the "Shift" and "MAM" keys on the keyboard. At the end of the desired measurement period, the controller should transmit the M0 program code to disable the MAM function. To acquire the results of the MAM measurement, the controller must call for each data result separately. This means the controller must transmit the program code M2, make the DMM a talker so that it can transmit the Min measurement value, make the DMM a listener so that it can be programmed with the M3 program code and thereby transmit the Avg measurement value and so on for each of the four measurement results from the MAM measurement cycles. Thus, for the controller to make a complete MAM measurement and acquire all the resulting data, the controller must transmit six program instruction strings; two (M6 and M0) to start and stop the MAM function followed by the M2 through M5 function codes to call for the results. The 6000, in turn, must transmit four measurement values: the minimum, the average, the maximum and the number of measurement samples.

3.4.21.3 When using MAM in conjunction with the GPIB, certain precautions should be taken to ensure that the 6000 isn't commanded over the bus while the Average is being up-dated internally. If the Average calculation is disrupted by GPIB programming, the accuracy of the average constant cannot be guaranteed, although the minimum, maximum and number of readings constants will not be jeopardized. For this discussion, all commands listed in Table 3.12 of the Operator's Manual are considered to be GPIB programming commands. It should be pointed out, however, that GPIB interface commands (such as Serial Poll) will not affect the accuracy of the average constant.

3.4.21.4 In order to guarantee the accuracy of the average constant, the programming of the MAM function should be handled as follows:

a. Program the MAM function as usual using the M1 or M6 command.

b. Delay as usual.

c. Via the GPIB, Program the 6000 to be a talker and take two readings from it. These two readings can then be thrown away.

d. Reprogram the 6000 as usual.

Steps should be taken to prevent delays of more than 10 milliseconds from occurring anywhere during or between steps c. and d. above. These steps may include the disabling of interrupts inside the controller and the execution of items c. and d. in succession.

3.4.21.5 This procedure guarantees that the 6000 will not be in the average calculation when reprogrammed via the GPIB. An HP 9825A example program using this procedure is shown.

```
0: wrt 700,"z1t1
 m1"
1: wait 5e3
2: red 700,2
3: red 700,2
4: wrt 700,"m0"
*21500
```

Command 6000 to:
Z1 initialize
T1 internal trigger
M1 MAM function

Delay while readings are taken

Take 2 readings

Remove from MAM function

3.4.22 Calibration Commands.

3.4.22.1 The Series 6000, in normal manual or remote operation, automatically goes into a self calibration cycle (Auto-Cal) on a predetermined time schedule. In order to disable the Auto-Cal the controller must transmit program code K0. To reestablish the Auto-Cal timing the controller transmits program code K1. To command an immediate Auto-Cal the controller transmits program code K2.

3.4.22.2 When commanding autocals from a controller, the programmer needs to know when the autocal has finished so that he can continue program execution. The best way to do this is to command the autocal and trigger the 6000 and then wait for the 6000 to output the resulting reading. For

```
0: wrt 700,"k2t3
 t0"
1: red 700,2
```

example, in the calculator program of figure xx, the 6000 is programmed to the hold mode (T3), an autocal is commanded (K2), and a reading is triggered (T0). The controller then waits for the reading to be transmitted to it from the 6000, which is an indication that the autocal has completed. The reading may then be processed as usual. If the programmer wishes to receive an SRQ when the autocal has completed, the D1 command may be added to the program string in the above example.

3.4.23 Equation Command.

3.4.23.1 To enter the instrument into the arithematic mode of operation, the controller must transmit the program code Q1. Upon receipt of this command, the instrument will perform the arithematic equation using the constants in storage. Before calling for the equation function, the controller should transmit any constants required for use in the equation or arithematic functions. If no constants have been transmitted and stored, prior to transmission of the program code Q1, the equation will have no effect on the present reading. This results when initialization sets the A constant at 0 and the constants B and C to 1.

3.4.24 Variable Manipulation Commands (A, B or C).

3.4.24.1 In a manner similar to that for manual operation, the controller can store or clear all arithmetic variables used in the mathematics equation. The codes for storing, clearing or the transmission of the variables are shown in Table 3.12. For example, to store 1.25 in the constant "A" location the controller must transmit 1.25A1.

3.4.25 Initialization Commands.

3.4.25.1 The controller can initialize the Series 6000 much in the same manner that the operator would use. In manual mode, the operator may depress the "Shift" and "Initialize" keys. This puts the instrument into the initialized state. The instrument can be initialized from the GPIB by using the command code Z1.

3.4.25.2 The Z1 command is equivalent to the program string F1, R0, T3, N0, P1, H0, J0, X0, M0, Q0, W0. The initialization command causes Null, HLL, MAM, Filter, Equation [(X-A)B/C] and Status Output (of Cal constants) to be disabled, Internal Reference and Numeric Display to be enabled and sets the DMM to DC Volts, Autorange and Hold condition.

3.4.26 Fast Analog-to-Digital (Fast A/D) Operation.

3.4.26.1 Measurement information can be obtained and transmitted at a high speed rate if the Fast A/D mode is used (Option 03 or 03SH).

3.4.26.2 GENERAL OPERATION PROCEDURES.

3.4.26.2.1 When programming the Fast A/D from the GPIB, it is important to note that program codes will produce a delay period before the 6000 is able to begin taking readings from the Fast A/D. Each command string sent to the 6000 will cause a delay of 1 timeout (reference Table 3.19) plus approximately 3 milliseconds. As an example, if the 6000 is in the DC function, then any command string sent to the DMM will cause a timeout of 30 milliseconds (for the DC function) plus approximately 3 milliseconds. After the command string has been executed and the 33 millisecond delay is completed, the 6000 will begin to take readings from the Fast A/D.

3.4.26.2.2 For most Fast A/D GPIB applications, the PØ command (disable front panel) should be used in conjunction with the IØ (Fast A/D) command. The PØ command will disable both the display and the keyboard of the 6000. If an IØ PØ command is sent by the controller, then a P1 command (enable front panel) must be sent before the 6000 is returned to local operation.

3.4.26.3 INTERNAL TRIGGER.

3.4.26.3.1 The Fast A/D can be programmed to trigger internally by sending the command string IØ PØ T1 to the 6000. The time between readings may then be controlled via the S command (delay).

3.4.26.3.2 In order to operate the Fast A/D at the fastest conversion rate, the controller should transmit ØØØ S1 which indicates no A/D delay. The numbers preceding the S1 command may range from ØØØ thru 255 (reference Table 3.12 for the delay formula).

3.4.26.3.3 As shown in Figure 3.27, the Fast A/D information is transmitted over the GPIB in two bytes by the 6000. Bits 1 thru 6 of each byte contain the data information (in two's complement), and bit 8 (DIO_8) is the byte identification bit (1 for the first byte and Ø for second byte).

3.4.26.3.4 The controller must be fast enough to accept each byte as it becomes available from the 6000. Therefore, the controller has to be faster than the 6000 in order to guarantee that no data will be lost. If the controller is too slow to accommodate the data rate of the 6000 certain bytes of the data will include a 1 in the overrun flag position ($DI07$).

3.4.26.3.5 If the overrun bit is detected, the delay between readings should be increased by programming a larger delay constant as referenced in paragraph 3.4.26.3.2 and Table 3.12.

3.4.26.4 EXTERNAL TRIGGER.

3.4.26.4.1 The Fast A/D can be programmed to wait for an external trigger by sending the command string IØPØ T2 to the 6000. The time between readings may then be controlled by applying trigger pulses to pin 14 or pin 15 of the Fast A/D or Sample and Hold Fast A/D connector.

3.4.26.4.2 When the 6000 is in the external trigger mode, the external triggers will be ignored until the internal delay period is completed (reference paragraph 3.4.26.2.1). At the end of the delay period, the 6000 will monitor the Fast A/D, waiting for an external trigger. The 6000 transmits the GPIB data bytes in the same format as described in subsection 3.4.26.3, except that the DIO_7 bit is always Ø .

3.4.26.4.3 If the external trigger rate exceeds the rate at which data bytes are taken from the 6000, then the DMM will output only the first byte of each two byte data word.

3.4.27 dB Commands.

3.4.27.1 Decibel measurement is handled in the remote mode very much the same as in bench operation mode. To enable dB measurement the controller transmits program code L1. To disable the function the controller transmits

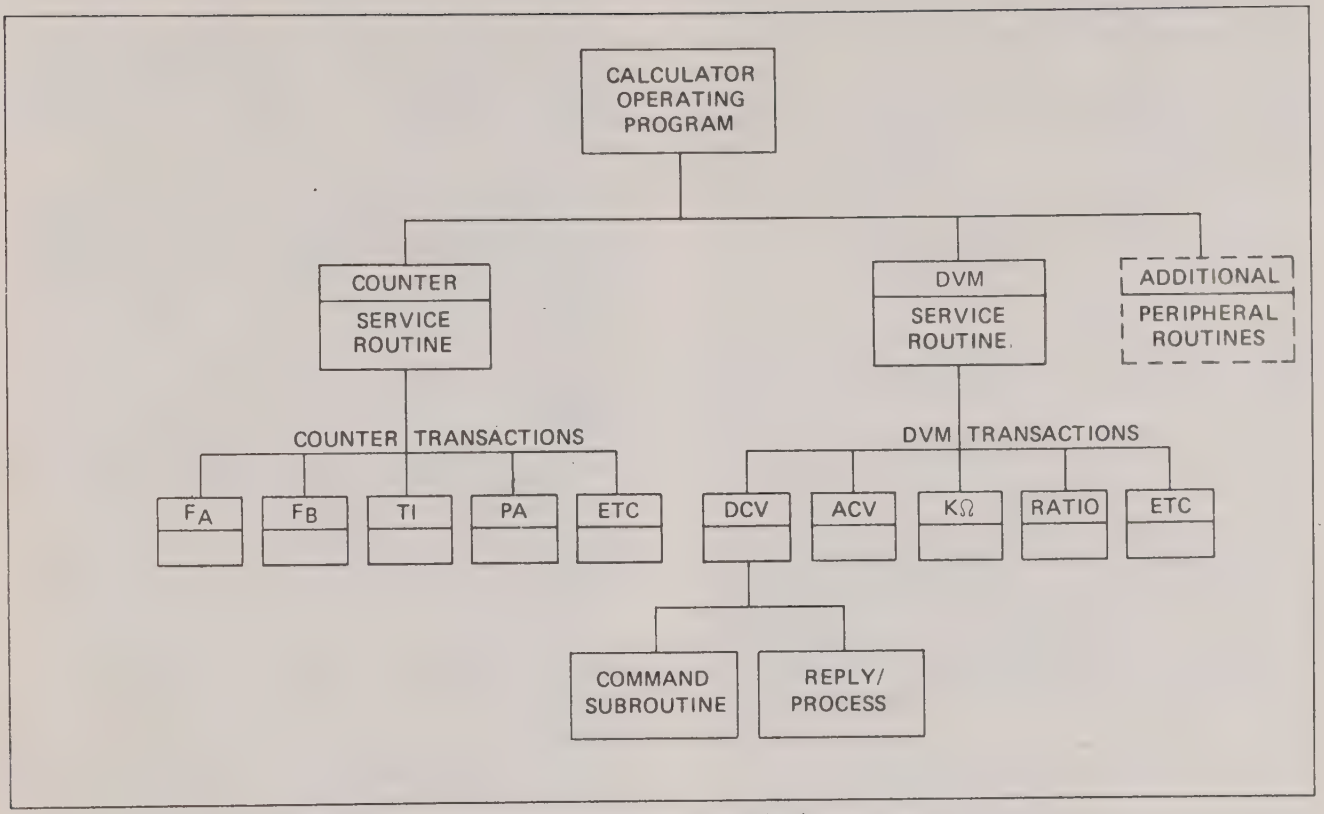


Figure 3.15 - Software Organization

L0. Just as in the bench operation mode the controller can change the value of the internal reference resistor from its normal 600 ohm value to a new desired value by transmitting the value followed by the program code L2.

3.4.28 Software Organization.

3.4.28.1 The following paragraphs are presented to acquaint the operator with the device messages used when operating the 6000 DMM and to explain the relationship of these device dependent messages to the user's overall software package.

3.4.28.2 A calculator, computer or other controller device software package usually includes a collection of transactions, service routines and subroutines for controlling all of the elements of a system. The relationship of the various parts of a typical software operating system are illustrated in Figure3.15. A complete operating system may include the main executive program, the keyboard monitor program, some form of statistical routine, an arithmetic or decision making routine and a set of peripheral servicing routines. Figure 3.15 illustrates a portion of a software package referred to as an operating system. The portion illustrated is a typical collection of peripheral service routines. These peripheral service routines are groups of subroutines known as transactions. Note that the illustration shows a service routine for a counter, a digital voltmeter and a number of additional peripheral equipments. A DVM service routine for the Series 6000 might include a number of transactions depending on the application of the instrument in the system. Each transaction will include the bus commands and device messages necessary to accomplish the specific function for each transaction. Note that the transactions shown are for DCV (DC volts), ACV (AC volts), KΩ (kilohms), Ratio and any number of other transactions necessary for the particular counter application. Note that under the DCV transaction block a further breakdown is illustrated: that of the command subroutine and the reply or process subroutine. This is the point in the overall software structure that the 6000 device messages appear.

3.4.28.3 VOLTMETER TRANSACTIONS.

3.4.28.4 Figure 3.16 illustrates a typical voltmeter transaction designed to operate the Series 6000. The left-hand column of the illustration titled Bus Action or Message contains a sequence of bus control line titles and device characters. The second column of the illustration indicates

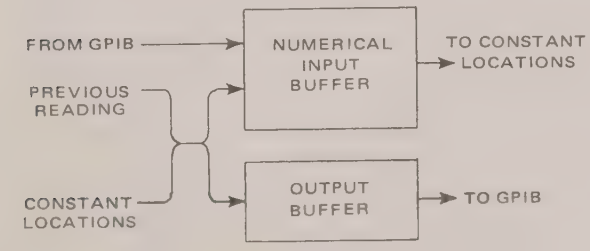
whether the controller or the DMM is controlling the bus or transmitting the characters. This column is titled Active Unit or Talker. The boxes to the right of the second column identify the portion of the transaction as the command subroutine or the reply subroutine. Note that the command portion of the transaction includes an interface message which establishes the talker/listener relationship and the device dependent message which instructs the DMM to perform a specific operation. Once the peripheral, in this case the 6000 DMM, has been programmed to perform a function, the controller transmits the second interface message to reestablish the listener/talker relationship and the 6000 makes the measurement and transmits the data over the interface bus.

3.4.29 Constant Manipulation From The GPIB.

3.4.29.1 There are 10 constant storage locations inside the 6000 which can be used regardless of whether the corresponding mode is selected or not. These locations are:

NULL
A
B
C
HLL_1 - HLL_6

3.4.29.2 Two main buffers are used in GPIB operation. The output buffer holds the ASCII characters which are waiting to be transmitted to the controller. The input buffer has two uses. During the entry of numerical constants from the bus, the input buffer is used as the holding register. Also, the input buffer is used to hold the number which was most recently transferred to the output buffer. For instance, if given the command N2, the input buffer will contain the value of the null constant. Also, the output buffer will contain the ASCII characters corresponding to the null constant. If a reading is taken, it will be placed in both the input and output buffers.



Bus Action or Message	Active Unit or Talker	Transaction	
IFC ATN UNLISTEN I TALK YOU LISTEN	 C C C	Interface Message	COMMAND Subroutine
F1 R5 T1	C C C	Device Dependent Message Command Characters	
ATN UNLISTEN YOU TALK I LISTEN	 C C C	Interface Message	REPLY Subroutine
+ 1 . 0 2 5 9 6 8 E + 0 1 CR LF	6000 6000	Peripheral Message Reply (Data, Status) Characters	

Figure 3.16 - 6000 DMM Transaction For DC Volts Measurement

3.4.29.3 Whenever a 'store' command such as H3 or A1 is executed, the present contents of the input buffer are stored in the given location. For instance, if a reading is completed and then a B1 command is given, the reading will be stored in B. If the command −2.05E−7A1 is executed, −2.05E−7 will be stored in A. A constant can be transferred from one location to another as follows: 1) move the constant to the buffers by using a transmit command, 2) transfer the contents of the input buffer to the new location with a store command. As an example, C2H4 moves the contents of C into HLL3 without disturbing C.

3.4.29.4 Whenever transfer of multiple constants over the bus (to the Model 6000) is required, the constants should be separated from each other by a CR (carriage return), a LF (line feed) or both. With most controllers this places a limit of one constant to the bus per command string.

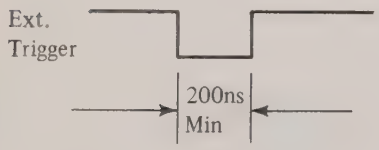
3.4.30 External Trigger.

3.4.30.1 DMM can be triggered via rear panel BNC connector after being placed in the 'Hold' mode via the keyboard (see Table 3.2 reference (23)) or after having received a T2 or T4 command via the GPIB (see Section 3.4.11).

Logic Compatability: TTL
Required Drive Capability

Source: 0 mA
Sink: 2 mA

Required Timing:



Maximum Fall Time: 1μS

Delay between falling edge of external trigger and start of reading: < 1μS

NOTE

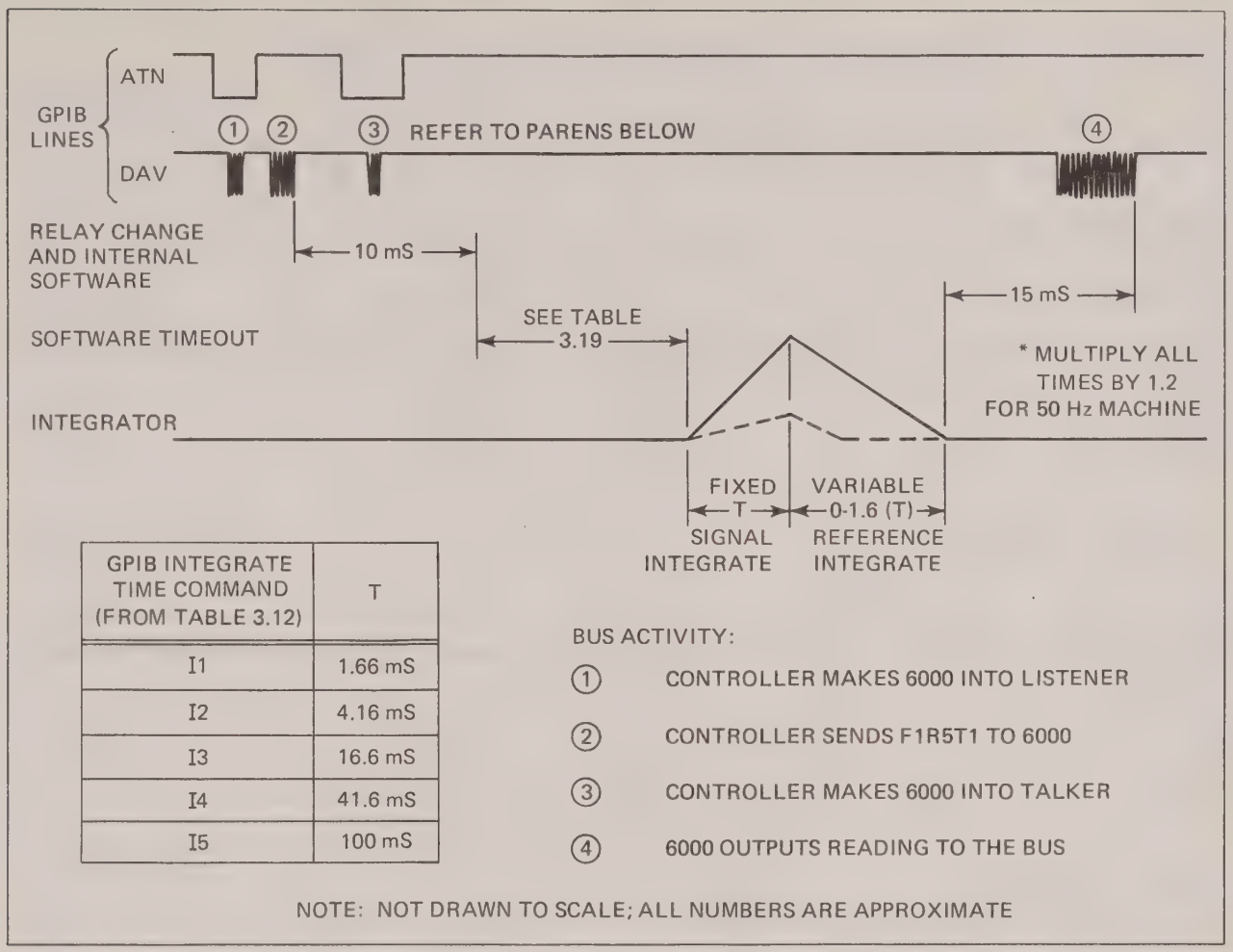
If a mechanical switch is used to generate the external trigger, contact bounce should be limited to 10μS at the waveform's falling edge and 0μS at the rising edge.

3.4.31 Read Rate Time Estimate.

3.4.31.1 The following GPIB Read Timing Program using the Hewlett Packard HP9825 calculator is presented as one example to estimate the DMM's throughput when successive readings are taken on different functions and ranges. This program string allows the programmer to estimate the time necessary to program the 6000 to a Function or Range, settle to 0.01%, take a reading, and output the reading to the bus.

Program String: Wrt 700, "FIR5"; red 700, A

3.4.31.2 Figure 3.17 shows the two GPIB lines ATN and DAV (Attention and Data Valid) along with the DMM's integrator waveform which indicates when a reading takes place. Also shown are the other delays needed to calculate the DMM's throughput time. From the figure, the total time = (10 ms) + (timeout time) + (signal integrate) + (reference integrate) + (15 ms).



GPIB INTEGRATE TIME COMMAND (FROM TABLE 3.12)	T
I1	1.66 mS
I2	4.16 mS
I3	16.6 mS
I4	41.6 mS
I5	100 mS

Figure 3.17 - Program/Read Timing Chart

Table 3.12 - Model 6000 GPIB Programming Codes

INTEGRATION TIME COMMANDS

6000 Operation	Program Code	Special Notes
Fast A/D	I0	Usable in internal trigger and external trigger modes only (T1, T2).
1.6 mS Integration Time	I1	4 1/2 digit display; automatically initiates Auto-Cal.
4 mS Integration Time	I2	5 1/2 digit display; automatically initiates Auto-Cal.
16 mS Integration Time	I3	
40 mS Integration Time	I4	6 1/2 digit display; automatically initiates Auto-Cal.
100 mS Integration Time	I5	

NULL COMMANDS

6000 Operation	Program Code	Special Notes
Disable Null	N0	
Enable Null	N1	Subtracts null constant from reading.
Store as Null	N2	Stores previous reading or entered constant as null constant.
Transmit Null	N3	Output null constant to GPIB.

Table 3.12 - Model 6000 GPIB Programming Codes (continued)

DISPLAY COMMANDS

6000 Operation	Program Code	Special Notes
Disable Numeric Display	P0	Reduces internal DVM cycle time by 3 ms for faster read rates, etc.
Enable Numeric Display	P1	

INTERRUPT COMMANDS

6000 Operation	Program Code	Special Notes
No SRQ when Data Ready	D0	
SRQ when Data Ready	D1	Informs controller when reading is ready to output to the GPIB

FUNCTION COMMANDS

6000 Operation	Program Code	Special Notes
DC Volts	F1	
AC Volts	F2	
AC Volts, DC Coupled	F3	RMS AC converter must be installed.
Ohms	F4	

RANGE COMMANDS

6000 Operation	Program Code	Special Notes
AUTO Range	R0	
10mV-1Ω	R1	Upranges automatically to 100 mV if overload occurs.
10mV-10Ω	R2	Remains on 10 mV range if overload occurs.
100mV-100Ω	R3	
1V-1KΩ	R4	
10V-10KΩ	R5	
100V-100KΩ	R6	
1000V-1MΩ	R7	
Auto-10MΩ	R8	
Auto-100MΩ	R9	

Table 3.12 - Model 6000 GPIB Programming Codes (continued)

TRIGGER COMMANDS

6000 Operation	Program Code	Special Notes
Trigger Immediate	T0	Normally used in conjunction with T3.
Internal Trigger	T1	Causes continuous readings.
External Trigger	T2	Waits for trigger from rear panel BNC or from Fast A/D trigger input.
Hold/Manual	T3	Waits for trigger from GPIB or from keyboard.
External Trigger with Timeouts	T4	Same as T_2 and T_3, except that an internal time delay is inserted to allow for analog settling times
Hold/Manual with Timeouts	T5	

EQUATION COMMAND

6000 Operation	Program Code	Special Notes
No Equation	Q0	Returns to normal operation.
Perform Equation $\frac{(X-A)B}{C}$	Q1	Enables offset and scaling.

VARIABLE MANIPULATION COMMANDS (A, B, or C)

6000 Operation	Program Code	Special Notes
Clear Constant	A0 or B0 or C0	A0 sets A to zero; B0 or C0 set B or C to 1.0.
Store as Constant	A1 or B1 or C1	Stores previous reading or entered constant into A, B, or C.
Transmit Constant	A2 or B2 or C2	Outputs present value of A, B or C to the bus.

INITIALIZE COMMANDS*

6000 Operation	Program Code	Special Notes
Initialize	Z1	Same as F1 R0 T3 N0 P1 H0 J0 X0 M0 Q0 W0 F1 DC R0 Autorange T3 Hold Mode N0 Disable NULL P1 Enable Display H0 Disable HLL J0 Disable Filter X0 Disable Ext. Ref. M0 Disable MMM Q0 Disable (X-A)B/C W0 Disable Status Output

* Note that a Z1 command differs slightly from the keyboard command "Initialize".

Table 3.12 - Model 6000 GPIB Programming Codes (continued)

EXTERNAL REFERENCE RANGE COMMANDS

6000 Operation	Program Code	Special Notes For use with "X" commands
10mV	Y2	DC software ratio only.
100mV	Y3	
1V	Y4	These reference ranges permitted with "X1".
10V	Y5 ←	This reference range selected automatically with "X5". These reference ranges OK with "X2", "X3", "X6", "X7".
100V	Y6	
1000V	Y7	

MIN-AVG-MAX COMMANDS

6000 Operation	Program Code	Special Notes
Disable MAM	M0	Returns to normal operation.
Clear & Enable MAM	M1	Initializes MIN, AVG, MAX and enables MAM.
Transmit MIN	M2	Outputs MIN to the GPIB.
Transmit AVG	M3	Outputs AVG to the GPIB.
Transmit MAX	M4	Outputs MAX to the GPIB.
Transmit Number of Samples	M5	Outputs Number of Samples to the GPIB.
Enable MAM	M6	Enables MAM without initializing the MIN, AVG or MAX.

CALIBRATION COMMANDS

6000 Operation	Program Code	Special Notes
Disable Auto Cal	K0	Prevents Auto-Cal from occurring automatically.
Normal Auto Cal Timing	K1	Allows Auto-Cal to initiate themselves automatically.
Do Auto Cal Now	K2	Perform an Auto-Cal immediately.

FAST A/D DELAY COMMANDS

6000 Operation	Program Code	Special Notes For use with "I0" and "T1" commands
Clear Delay	S0	Same as "000S1"; sets fast A/D delay = 0 and inhibits data overrun error check.
Store Delay	S1	"nnnS1" stores a delay constant where nnn is between 000 and 255. A non-zero delay enables data overrun error check. "S0" or "0S1" gives a delay of 79 μs. } 60 Hz line "nnnS1" gives a delay of (95+ nnn•44) μs. } voltage only

dB COMMANDS

6000 Operation	Program Code	Special Notes "H1" and "L1" cannot be performed simultaneously
dB Disable	L0	Returns to normal operation.
Enable dB	L1	Enables dB function.
Store as dB Resistance	L2	Stores the previous reading or entered constant as the reference resistance for dB calculations.

STATUS OUTPUT COMMANDS

6000 Operation	Program Code	Special Notes
No Status Output	W0	Returns to normal operation.
Output Cal Constants for this function and range	W1	Outputs positive offset, negative offset, positive and negative scale factors (4 constants) and then returns to normal operation. When using W1 it should be the last command in the program string.

FAST A/D CONFIGURATION COMMANDS

6000 Operation	Program Code	Special Notes For use with S/H Fast A/D
Fast A/D to Isolator	G0	Connects Fast A/D input to DVM input terminals via the isolator.
Fast A/D to rear connector	G1	Connects Fast A/D input to Fast A/D connector on back panel.

Table 3.12 - Model 6000 GPIB Programming Codes (continued)

HIGH-LOW-LIMIT COMMANDS

6000 Operation	Program Code	Special Notes "H1" and "L1" cannot be performed simultaneously
Disable HLL	H0	Returns to normal operation.
Enable HLL Function	H1	See text for description of output format.
Enter HLL Constants 1 thru 6	H2 thru H7	Stores the previous reading or an entered constant as HLL 1 thru HLL 6.
Transmit all 6 Constants	H8	Transmitted in reverse order (HLL6...HLL1) over the GPIB When using H8 it should be the last command in the program string.
Initializes HLL Constants 1 thru 6	H9	HLL constants are cleared.

FILTER COMMANDS

6000 Operation	Program Code	Special Notes
Filter Out	J0	
Filter In	J1	Selects the 4-pole active filter.

FRONT/REAR INPUT COMMANDS

6000 Operation	Program Codes	Special Notes
Front Input	V0	Measurements taken from the front input terminals.
Rear Input	V1	Measurements taken from the rear input terminals.

EXTERNAL REFERENCE FUNCTION COMMANDS

6000 Operation	Program Code	Special Notes
Internal Reference	X0 or X4	Normal mode of operation.
Software Ratio DC	X1	Reference applied to input terminals which were not selected via the "V" command.
Software Ratio AC	X2	
Software Ratio AC, DC Coupled	X3	
Hardware Ratio DC	X5	Reference applied to external reference terminals.
Hardware Ratio AC	X6	
Hardware Ratio AC, DC Coupled	X7	

3.5 PARALLEL BCD OPERATION.

3.5.1 This subsection presents information on the Parallel BCD operation in the 6000.

3.5.2 Printer Output J212.

3.5.2.1 Through this connector the 6000 supplies BCD representations of the decimal display; various flags or indicators of the mode of operation, function and range; and a print command. Provision has also been made for 60 Hz instruments to accept a fast (17 readings per second maximum) or a superfast (50 readings per second minimum) read command. In 50 Hz units, the fast command obtains 14 readings per second, minimum, and the superfast command 49 readings per second.

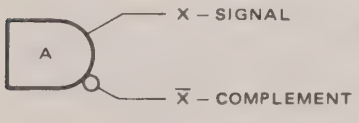
3.5.3 Program Input J209.

3.5.3.1 Through this connector the 6000 receives externally generated signals that select the function, range, mode of operation, auto calibration and initiate the read commands.

3.5.4 Logic Levels And Electronic Interface.

3.5.4.1 TTL-compatible positive-true logic levels are used in the 6000. In some instances, however, complementary signals are used. These terms are more specifically defined below:

Signals and Their Complements –



WHERE:

X	$\overline{X}$
1	0
0	1

3.5.4.2 If the non-inverting output of gate A is defined as signal X, then it follows that the inverting output is $\overline{X}$; in other words, the complement of X is $\overline{X}$. The truth table shows that the two signals X and $\overline{X}$, are by definition, in opposite logic states (see Table 3.13).

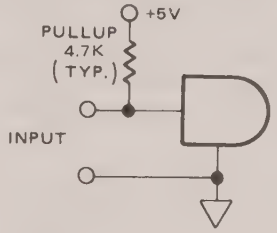
Table 3.13 - Positive True Logic Relationships

Signal	Logic State	Voltage Level of Output Line "X"	Voltage Level of Output Line "$\overline{X}$"
"X"	True or "1"	2.4 - 5.0 Volts	0.0 - 0.4
	False or "0"	0.0 - 0.4 Volts	2.4 - 5.0

3.5.4.3 As seen above, if gate A has a true or "1" level on output X, its voltage level is the most positive of the two ranges present, and output $\overline{X}$ must be in a false or "0" state with the lowest or most negative voltage range present. The reverse would be true for a false or "0" level on output X.

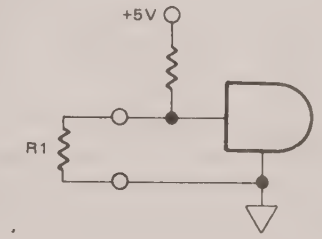
3.5.4.4 DRIVING THE INPUTS.

3.5.4.4.1 All inputs are low power schottky TTL compatible and most are the equivalent of one 74LS series TTL input with a pull-up resistor for contact closure operation.



3.5.4.5 TTL LOADING CONDITIONS.

3.5.4.5.1 To input a "1" level the pull-up resistor will supply the necessary source current (40 μA) to maintain the minimum 2.4 volts. In fact, the pull-up resistor will maintain a one level as long as the input source resistance (R1) to ground is greater than 7.5K ohms.

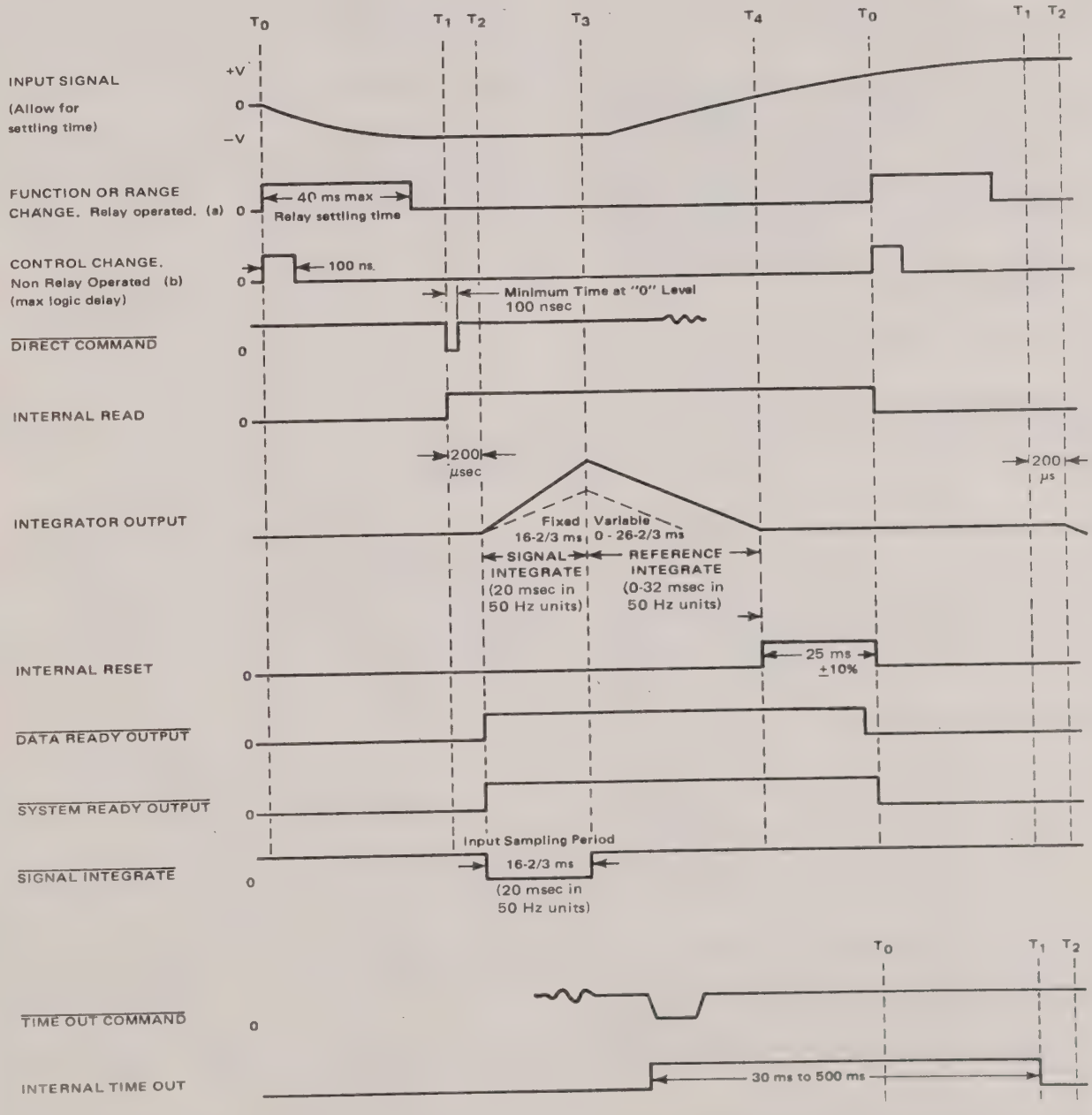


3.5.4.5.2 To input a "0" level, at least .5 ma of current must be sinked maintaining the input voltage below 0.4 volts. This requires a resistance to ground of 800 ohms or less.

3.5.4.6 EXCEPTIONS TO INPUT LOADING CONDITIONS.

a. $\overline{\text{Program Storage}}$ Input (J209, pin B-18) is the standard TTL inputs and requires a minimum 2 ma sinking current, or 200 ohms or less to common.

b. Maximum input voltage level, referenced to common, must not exceed 5.5 volts peak. Otherwise, gate destruction will occur.

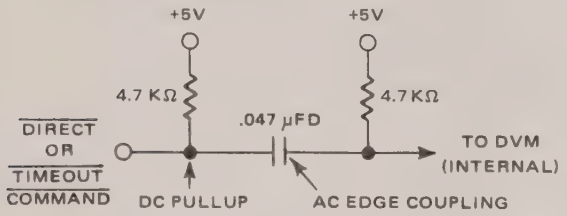


(a) Such as: Function, Range, Filter and Ratio.
(b) Such as: Super Fast, Data Disable, Program Storage System Control and Hold

Except as noted:
Pulses are the same for 50 & 60 Hz

Figure 3.18 - Measurement Sequence

c. The $\overline{\text{Direct}}$ and $\overline{\text{Time Out Commands}}$ are AC coupled with pull-up resistors to +5 volts. These inputs are compatible with TTL outputs or contact closures to ground. The AC coupling does require that rise and fall times be less than 100 μseconds. This input circuit is illustrated below:



d. Digital output common can be floated as high as 200 VDC above power line ground.

3.5.4.7 TTL OUTPUT CAPABILITIES.

3.5.4.7.1 The 6000 electrical outputs are specified to drive two TTL inputs such as described in the TTL loading section. Summary:

False: 0 to +0.4V
True: +2.4 to +5.0V
Fan out: 2 minimum
Maximum Capacitance Load: 500 pF

3.5.4.8 TIMING SEQUENCE.

3.5.4.8.1 The standard remote mode of operation of the 6000 is to initiate a reading sequence with each Direct Command received through the programmer, providing that sufficient time has been allowed between commands for the reading to be completed. This reading sequence is illustrated in Figure 3.18.

$T_1 - T_0$ During this period the input signal must finish settling to within the desired accuracy. Any control changes involving the 40 msec relay settling time (a) can be completed; other logic control inputs (b) can also be changed.

$T_2 - T_1$ The $\overline{\text{Direct Command}}$ signal, which is AC coupled, must meet the following conditions:

a. Rise and fall times less than 100 μsec.

$T_3 - T_2$ The period of signal integration lasts for 16-2/3 msec (60 Hz line frequency; 20 msec in 50 Hz units). During this time the integrator charges to a voltage proportional to the input voltage. This is the input sampling period.

$T_4 - T_3$ During this period, the integrator is isolated from the input signal, and is discharged at a precise current. The time the integrator requires to discharge to a level equal to its voltage at T_2 is proportional to the input voltage. This time is measured by an internal counter and stored.

$T_0 - T_4$ This 15 mseconds (± 10%) is required for the microprocessor to calculate the actual reading.

$T_1 - T_0$ If the next read command is a $\overline{\text{Direct Command}}$, this period must be made long enough to allow for the condition covered in the first cycle; however, if the next command is a $\overline{\text{Timeout Command}}$, this period can approach zero since the necessary timeout to satisfy these conditions are automatically programmed.

3.5.4.9 OTHER READ COMMAND OPTIONS.

3.5.4.9.1 In addition to the Direct Command, there are two other programmable read commands, as illustrated in Figure 3.18.

a. $\overline{\text{Time Out Command}}$: Again, this is an AC coupled input which must have rise and fall times of less than 100 μseconds but must remain in a "0" state for at least 0.1 μsecond. The timeouts given in Table 3.19 for various combinations of ranges and functions ranging from 30 mseconds to 500 mseconds will be automatically inserted before the internal read command is generated. If this command is wired to the System Ready Output on J212-pin 43, fully automatic reading with timeouts is achieved.

NOTE

The internal delay is not adequate for settling time on the 100 VDC, 1000 KΩ, 10 MΩ, 100 MΩ ranges, or any AC range. Therefore, the timeout command, providing timeout delays listed in table 3.19, must be used to initiate accurate readings on these ranges unless a fixed range and function have been programmed and the input has been present longer than the timeout period.

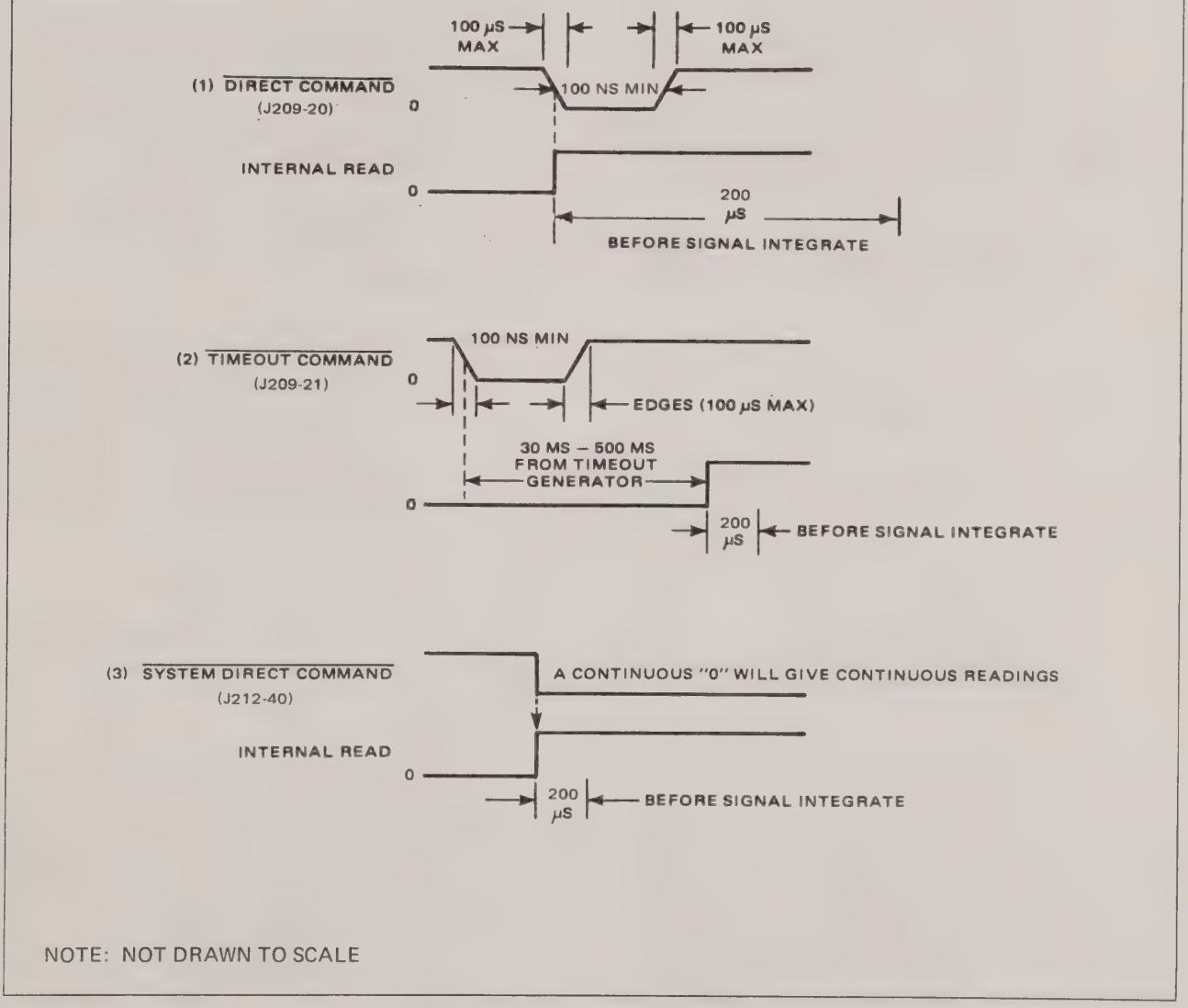


Figure 3.19 - Command Timing

b. $\overline{\text{System Direct Command}}$: While the other two read commands were AC coupled and programmed through the Program Input Connector (J209), this command is DC coupled and programmed through the Printer Output Connector (J212). The $\overline{\text{System Direct Command}}$ must remain in the "0" state for at least .1 µseconds to generate the internal read command. If this command is tied to ground, the 6000 will recycle at its maximum reading rate with no time-outs.

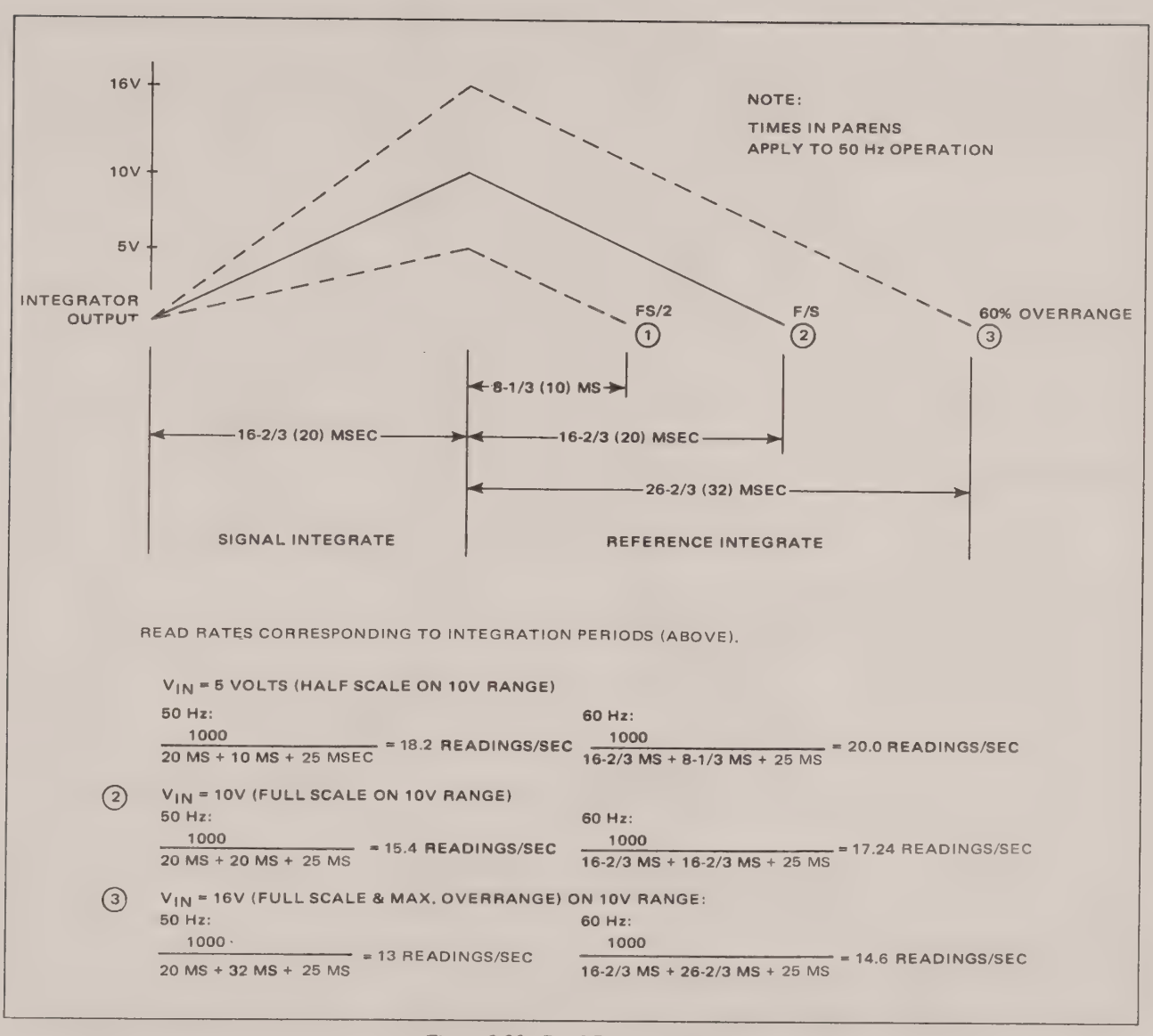

16V
10V
5V
INTEGRATOR OUTPUT
NOTE:
TIMES IN PARENS
APPLY TO 50 Hz OPERATION
FS/2
F/S
60% OVERRANGE
1
2
3
8-1/3 (10) MS
16-2/3 (20) MSEC
16-2/3 (20) MSEC
26-2/3 (32) MSEC
SIGNAL INTEGRATE
REFERENCE INTEGRATE
READ RATES CORRESPONDING TO INTEGRATION PERIODS (ABOVE).
V_{IN} = 5 VOLTS (HALF SCALE ON 10V RANGE)
50 Hz:
1000 / 20 MS + 10 MS + 25 MSEC = 18.2 READINGS/SEC
60 Hz:
1000 / 16-2/3 MS + 8-1/3 MS + 25 MS = 20.0 READINGS/SEC
(2) V_{IN} = 10V (FULL SCALE ON 10V RANGE)
50 Hz:
1000 / 20 MS + 20 MS + 25 MS = 15.4 READINGS/SEC
60 Hz:
1000 / 16-2/3 MS + 16-2/3 MS + 25 MS = 17.24 READINGS/SEC
(3) V_{IN} = 16V (FULL SCALE & MAX. OVERRANGE) ON 10V RANGE:
50 Hz:
1000 / 20 MS + 32 MS + 25 MS = 13 READINGS/SEC
60 Hz:
1000 / 16-2/3 MS + 26-2/3 MS + 25 MS = 14.6 READINGS/SEC

Figure 3.20 - Read Rate vs. Input

3.5.4.10 READING RATES.

3.5.4.10.1 In Figure 3.20, integrator operation with three different input signal levels is illustrated: half scale, full scale, and 160% of full scale (full scale is defined as 100000 on any range). The figure shows that the maximum reading rate is a function of the input signal. The signal integrate period and internal reset remain fixed while the reference integrate period can vary from 0 to 32 mseconds. Therefore the maximum read rate could vary from 14.9 to 31.6 reading per second.

3.5.4.11 SUPERFAST.

3.5.4.11.1 The Superfast reading mode (programmed through either the PRINTER OUT or PROGRAM INPUT

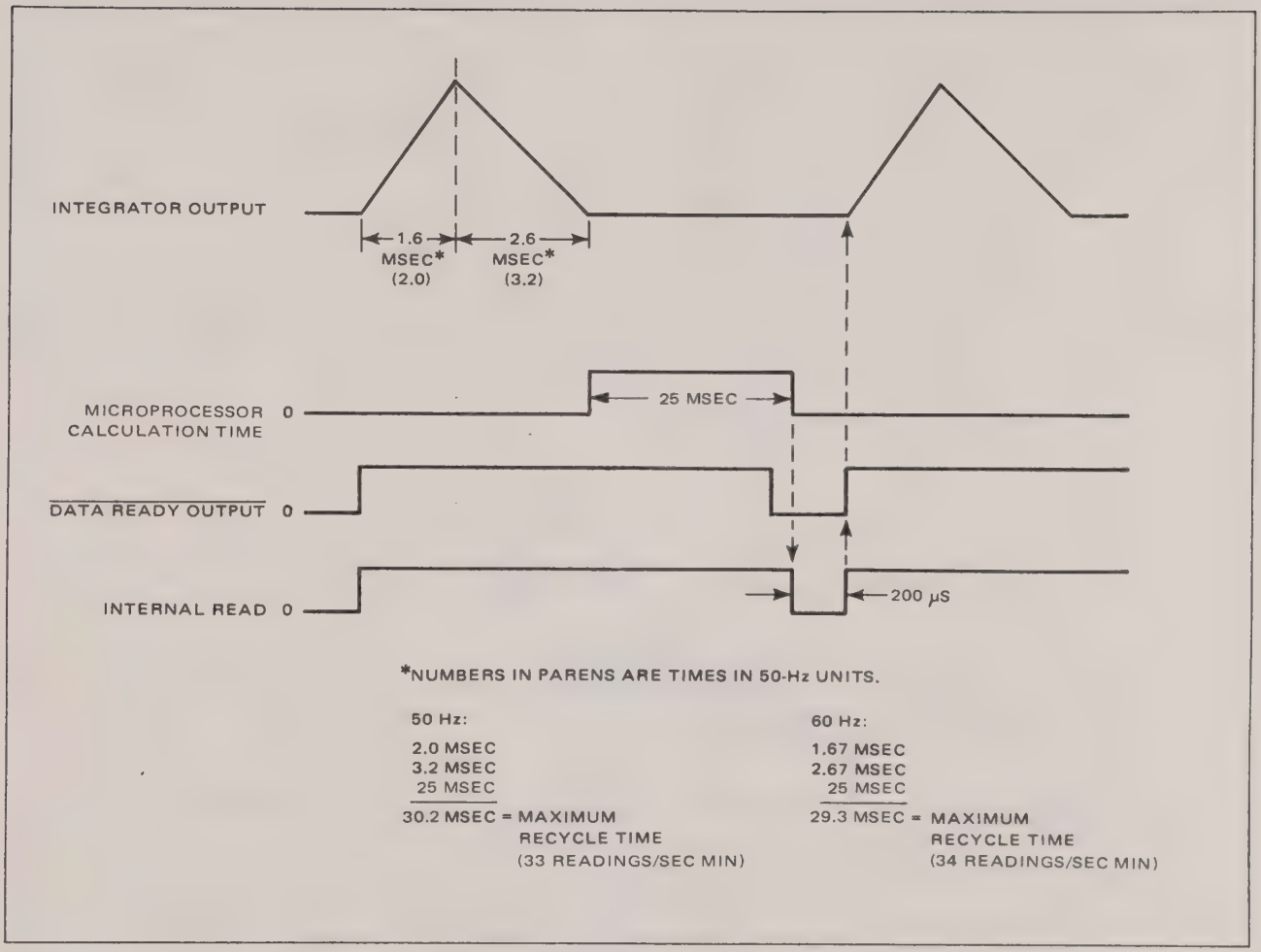


Figure 3.21 - Superfast Read Rate (Worst Case)

connector) increases the minimum reading rate from 14.6 to 34 readings per second (50 Hz: 13 to 33 r/s). This is done at the expense of losing the least-significant digit which is reset to zero (blanked out on readout). The signal integration period is reduced from 16-2/3 msec to 1-2/3 msec (50 Hz: 20 msec to 2 msec). This and the resulting reference integrate period reduce the maximum recycle time from 68.3 msec to 29.3 msec (50 Hz: 77 msec to 30.2 msec), thereby yielding the 34 reading per second figure (33 r/s with 50 Hz). Timing changes are shown in Figure 3.20.

3.5.5 Printer Output.

3.5.5.1 The printer output connector is a 3M type D 50 pin connector. Pin assignments are shown in Table 3.14. All outputs are referenced to digital ground pin 22.

3.5.5.2 NUMERICAL DATA.

3.5.5.2.1 Numerical data appears as positive true, four-line BCD code, as shown in Figure 3.15. The designator of each line identifies the digit and weight. For example: Pins 30, 29, 28, and 27 are designated 1_2, 1_8, 1_4, and 1_1, consecutively. The 1 indicates these lines correspond to the units or least significant display; the 2, 8, 4, and 1 subscripts indicate the binary weight of each line.

CAUTION

True output lines are not short-circuit proof. Accidental grounding may damage the output circuitry.

Table 3.14 - Pin Assignments J201 (Printer Output)

J212 Pin No.	Data Out
47	AC
46	Ratio
45	DC
44	Hold (Flag)
43	System Ready Out
42	Super Fast In
41	Data Disable In
40	System Direct Cmd
39	+ Polarity
38	– Polarity
37	Data Ready Out
36	No
34	Rng D8
33	Rng A1
32	Rng C4
31	Rng B2
30	1_2
29	1_8
28	1_4
27	1_1
26	10_2
1	10_8
2	10_1
3	10_4
4	100_2
5	100_8
6	100_1
7	100_4
8	$1K_2$
9	$1K_8$
10	$1K_1$
11	$1K_4$
12	Signal Int
13	$10K_2$
14	$10K_8$
15	$100K_1$
16	$10K_{11}$
17	$10K_1$
18	Filter
19	System Control (Flag)
20	+5V
21	Ohms
22	Digital Gnd

3.5.5.2.2 Polarity is indicated in positive true format on pin 39 (positive) and pin 38 (negative). The positive polarity line is true when the function output is AC or ohms. If the instrument overranges, the polarity bit is not updated since no axis-crossing has occurred.

3.5.5.3 FUNCTION DATA.

3.5.5.3.1 Function outputs appear on pins 45, 46, 47 and 21 in their true format. For example: with AC function selected, AC is true and is indicated by a true level on the corresponding line.

3.5.5.4 RANGE DATA.

3.5.5.4.1 Range data appears in four-line BCD code on pins 31 through 34. Range codes are described in Table 3.15.

3.5.5.5 "NO" INDICATION.

3.5.5.5.1 The NO line (pin A12) is the same as the NO indicator on the readout. The line is true if a function or range is selected for which the particular instrument is not equipped. Overrange is indicated by a true NO line plus 'OL' on the display.

3.5.5.6 STATUS OUTPUT LINES.

3.5.5.6.1 The following outputs indicate the status of the conversion process within the instrument.

a. DATA READY. This line (pin 37) remains true during the signal and reference integration periods plus any overrange time and microprocessor calculation time, if required. The line drops to the false level to indicate to the printer that the measurement is complete and output data can be printed (Printer Command). Minimum false level time is 2 mseconds.

b. HOLD FLAG. A true level on this line (pin 44) indicates that the instrument is in the Hold mode. A reading can be initiated by one of the following commands:

1. SYSTEM DIRECT COMMAND (J212-40)
2. DIRECT COMMAND (J209-20)
3. TIMEOUT COMMAND (J209-21)

Table 3.15 - Range Codes (Printer Output)

Range	A (J212-33)	B (J212-31)	C (J212-32)	D (J212-34)	Dec Value
10Ω	0	1	0	0	2
0.1V 0.1 KΩ	1	1	0	0	3
1V 1 KΩ	0	0	1	0	4
10V 10 KΩ	1	0	1	0	5
100V 100 KΩ	0	1	1	0	6
1000V 1000 KΩ	1	1	1	0	7
10 MegΩ	0	0	0	1	8
100 MegΩ	1	0	0	1	9

c. $\overline{\text{SYSTEM READY}}$. This line (pin J212-43) drops to a false level to indicate that the instrument can now initiate a new reading at the first available read command.

d. $\overline{\text{SIGNAL INTEGRATE}}$. This line (pin J212-12) becomes true at the end of the signal integration period. After this time, the input signals may be changed in preparation for the next reading. The input signal need remain constant only while the instrument is in Signal Integrate, indicated by this line in the false state. For example, the 1-2/3 msec sample time in Superfast could be used in slow sample and hold applications.

3.5.5.7 INPUT CONTROL LINES.

a. $\overline{\text{DATA DISABLE}}$. A contact closure to ground or a false logic level applied to this line (J212-41) inhibits the $\overline{\text{DATA READY}}$ output (Print) pulse.

b. $\overline{\text{SYSTEM CONTROL}}$. A contact closure to ground or a false logic level on this line (J209-16) disables all front panel operating controls, except 'Shift' and 'Local'. Operation of the instrument is then under control of the Remote Program input. This command duplicates operation of the 'Shift' 'Local' switch on the front panel. 'Shift' 'Local' switch can be pressed from the front panel to operate the system under the control of program input. 'Shift' 'Local' is used in toggle mode - by pressing the keys again system will be in local mode.

c. $\overline{\text{SUPERFAST}}$. A contact closure to ground or a false logic level applied to this line (J212-42 or J209-15) decreases the conversion time of the instrument while sacrificing the least-significant digit. This mode is described in paragraph 3.5.4.11. Because of the superfast read rate, do not use this mode with Autorange.

3.5.5.8 $\overline{\text{SYSTEM DIRECT COMMAND}}$.

3.5.5.8.1 To externally initiate a measurement with this command, the instrument must be in the Hold mode. Then, a contact closure to ground or a false logic level to this line (J212-40) generates a read command. Minimum false level time is .1 μsec. Continuous readings at the maximum read rate are obtained by tying this line to ground. Read commands delayed by 25 msec ± 10% (for calculation time) are then generated automatically.

3.5.6 Remote Programming.

3.5.6.1 The instrument accepts commands made through **PROGRAM INPUT** connector J209 on the rear panel. Pin assignments of J209 are shown in Table 3.16. Commands

Table 3.16 - Pin Assignments J209 (Program Input)

J209 Pin No.	Data Out
1	$\overline{\text{A1}}$
2	$\overline{\text{C4}}$
3	$\overline{\text{B2}}$
4	$\overline{\text{D8}}$
5	$\overline{\text{Hold}}$
6	$\overline{\text{AC}}$
7	$\overline{\text{Ohm}}$
8	$\overline{\text{Filter}}$
9	$\overline{\text{Ratio}}$
14	$\overline{\text{Data Inhibit}}$
15	$\overline{\text{Superfast}}$
16	$\overline{\text{System Control}}$
17	+5V
18	$\overline{\text{Program Storage}}$
19	Digital Ground
20	$\overline{\text{Direct Command}}$
21	$\overline{\text{Timeout Command}}$
22	$\overline{\text{Auto Cal}}$

Table 3.17 - **Function Programming**

$\overline{DC}$	NC
$\overline{AC}$	J209-6
$\overline{OHMS}$	J209-7
$\overline{RATIO}$	J209-9
$\overline{FILTER}$	J209-8

are made by a switch closure from the appropriate pin to ground or by low power schottky TTL logic levels as described earlier.

3.5.6.2 $\overline{SYSTEM\ CONTROL}$.

3.5.6.2.1 A contact closure to ground or a false logic level applied to pin J209-16 disables all front panel operating controls, except 'Shift' and 'Local'. Operation of the instrument is then under control of the remote program input. This line duplicates the 'Shift' 'Local' switch on the front panel.

3.5.6.3 FUNCTION PROGRAMMING.

3.5.6.3.1 The desired function is selected by applying a ground or false logic level to the appropriate pin (Table 3.17).

3.5.6.3.2 The internal delay is not adequate for settling time on the 100 VDC, 1000 Kilohm, 10 Megohm, 100 Megohm, and all AC ranges. Therefore, the timeout command, providing timeout delays listed in Table 3.19, must be used to initiate readings on these ranges unless the input is fixed with range and function predetermined.

3.5.6.4 RANGE PROGRAMMING.

3.5.6.4.1 Range programming is selected by applying false logic levels in BCD code to the four range lines described in Table 3.18. With no lines programmed, Autorange is automatically selected.

Table 3.19 - **Timeouts**

DC	40 msec
1 Ohm to 1 Megohm	40 msec
10 Meg*	40 msec
100 Megohm	400 msec
Filter	630 msec (plus function timeout)
AC(fixed range, no filter)	240 msec
AC+Filter(&Autorange)	860 msec
*Use filter for <.01% error	

3.5.6.5 + FIVE VOLTS.

3.5.6.5.1 This voltage, +5 volts ± 5%, from the logic power supply is available at pin J209-17 for external use. Current output is .1A, maximum.

3.5.6.6 HOLD.

3.5.6.6.1 The Hold line is selected by a contact closure or a false logic level on pin J209-5. Hold is required when using either of the three read commands.

3.5.6.6.2 With the Hold line selected, changing the Function or Range function generates an internal reading. The System Ready output is directly set or reset by the Signal Integrate line as shown in Figure 3.22. If System Ready Output is used to generate readings, it will create a valid reading after the Function or Range is changed.

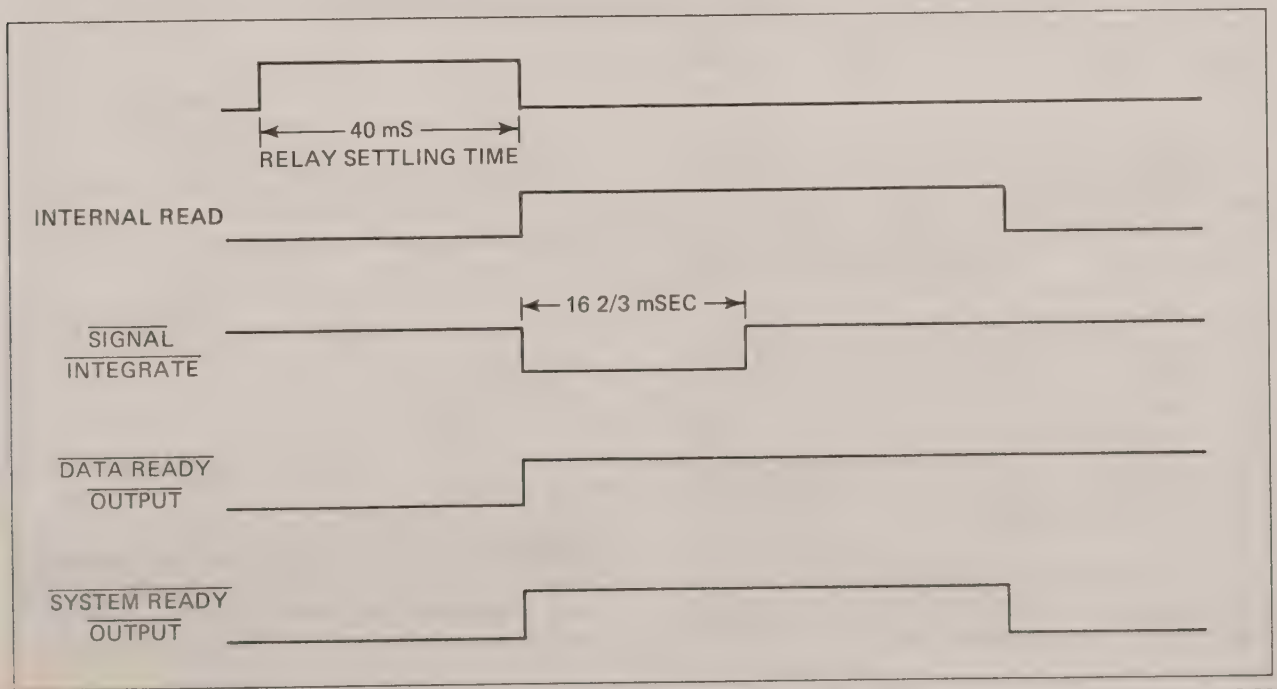


Figure 3.22 - Internally Generated Timing Chart

Table 3.18 - **Range Codes (Programmer)**

Range	$\overline{A}$ (J209-1)	$\overline{B}$ (J209-3)	$\overline{C}$ (J209-2)	$\overline{D}$ (J209-4)	Dec Value
AUTO	1	1	1	1	0
10Ω	1	0	1	1	2
0.1V 0.1 KΩ	0	0	1	1	3
1V 1 KΩ	1	1	0	1	4
10V 10 KΩ	0	1	0	1	5
100V 100 KΩ	1	0	0	1	6
1000V 1000 KΩ	0	0	0	1	7
10 MegΩ	1	1	1	0	8
100 MegΩ	0	1	1	0	9

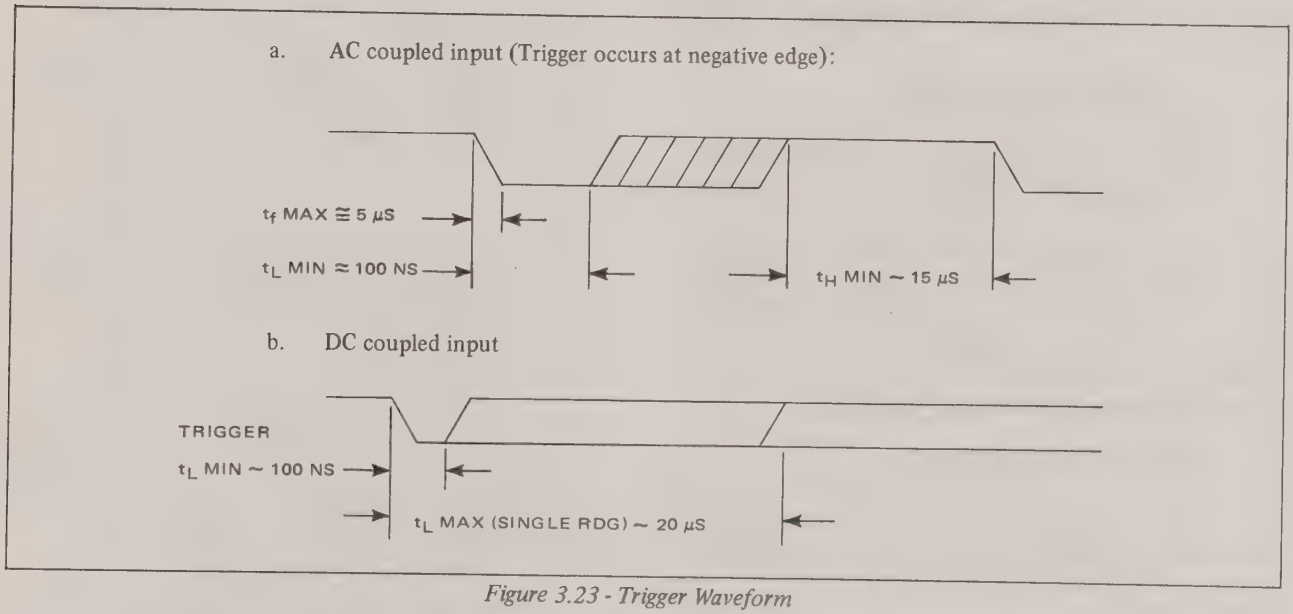

a. AC coupled input (Trigger occurs at negative edge):
t_f MAX ≅ 5 μS
t_L MIN ≈ 100 NS
t_H MIN ~ 15 μS
b. DC coupled input
TRIGGER
t_L MIN ~ 100 NS
t_L MAX (SINGLE RDG) ~ 20 μS

Figure 3.23 - Trigger Waveform

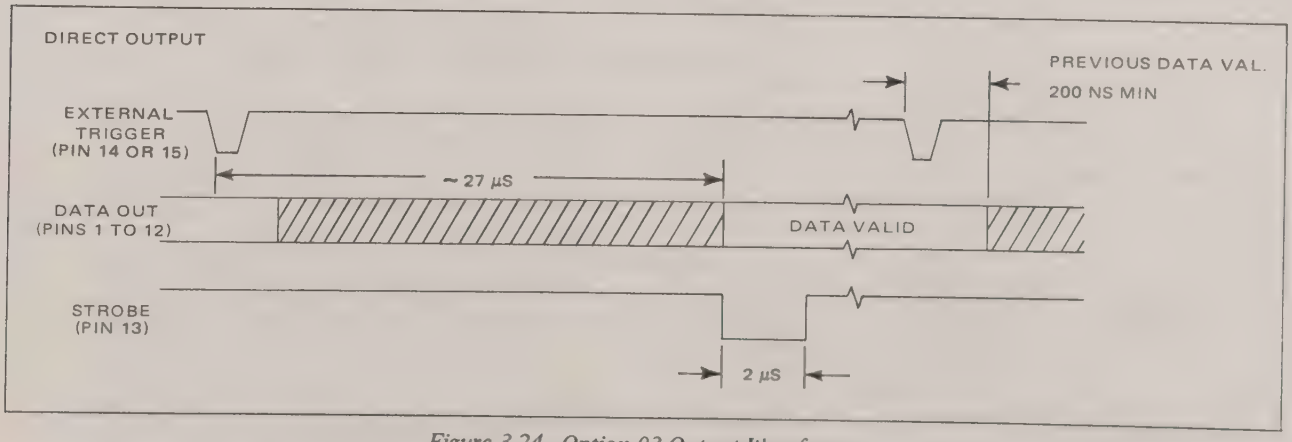


Figure 3.24 - Option 03 Output Waveforms

3.5.6.7 READ COMMANDS.

3.5.6.7.1 Either of two read command lines can be selected by a contact closure to ground or by a negative logic level applied to the appropriate pin. J209-20. $\overline{\text{DIRECT COMMAND}}$, commands a new measurement if applied after fifteen millisecond delay, and if the command is present for .1 μseconds. Pin J209-21, $\overline{\text{TIMEOUT COMMAND}}$, starts a new measurement after fifteen milliseconds plus a

Table 3.20 - **Maximum Input Voltage**

CAUTION Do not exceed the following maximum inputs.	
DC	1000 VDC or RMS AC All ranges
AC	1000 RMS to 15 kHz decreasing 20 dB/ decade to 15V RMS at 1 MHz
RATIO	Input: DC/DC hardware ratio Reference: +10.5V, +1 VDC
OHMS	±500V DC or Peak AC
GUARD	Voltage between GUARD AND – INPUT must not exceed 250 volts or damage to the instrument may result

timeout delay to allow for internal settling time of the measured signal. TIMEOUT COMMAND cannot be commanded before the previous 25 msec delay.
generator stores the reading.

3.5.6.8 TIMEOUTS.

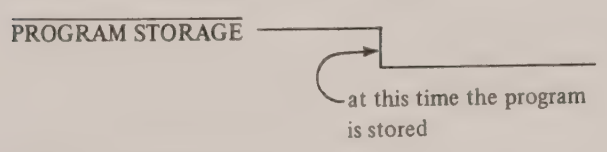
3.5.6.8.1 Timeout periods for each function are listed in table 3.19. In Autorange, the indicated delays are taken following each range change.

3.5.6.9 DATA INHIBIT.

3.5.6.9.1 A contact closure or false logic level on pin J209-14 inhibits DATA READY OUTPUT (Print pulse) from being generated.

3.5.6.10 PROGRAM STORAGE.

3.5.6.10.1 A false level (equivalent to three TTL inputs) on pin J209-18 will store all the programmed inputs except the Direct and Timeout commands and Auto-Cal as they existed on the negative edge of this command (see diagram below.



3.5.6.11 SUPERFAST.

3.5.6.11.1 A contact closure to ground or a false logic level applied to pin J209-15 decreases the signal integrate and the reference integrate times (see paragraph 3.5.4.11). This provides the maximum reading rate in the DIRECT COMMAND mode of operation. Because of the high reading rate, Superfast must be programmed with a fixed range rather than Autorange.

3.5.6.12 AUTO CALIBRATION.

3.5.6.12.1 A contact closure to ground or false logic level on this line will initiate the auto calibration procedure and the system will go through complete calibration. If this input is held low, it will disable auto calibration. If this input is not held low, it will go through the auto calibration programmed by main program.

3.6 FAST A/D (OPTIONS 03 AND 03 SH).

3.6.1 These options provide for high speed digitizing of analog waveforms.

3.6.2 The Fast A/D may be controlled through the keyboard, via the GPIB or through its interface connector (Figure 2.2) located on the rear panel.

3.6.3 The Fast A/D may be triggered at rates up to 30 KHz. The maximum read rate is, however, limited to 250 readings per second when the output data is to be read from the 6000 display or 6000 readings per second when the GPIB is used. The full conversion speed is available only when the data is transmitted via its interface connector. The conversion time will be less than 29 μsec for all modes.

3.6.4 Two mutually exclusive trigger inputs are available, AC coupled and DC coupled. Figure 3.23 shows the required waveforms.

3.6.5 The direct output provided from the rear panel is in binary 2's complement format. Each output can drive 2 TTL loads. The output is scaled to +20.47 and –20.48 volts full scale. Thus, octal 3777 indicates +20.47V while octal –3777 indicates –20.47V.

3.6.6 Output waveforms for Option 03 are shown in Figure 3.24 and output waveforms for Option 03SH are shown in Figure 3.25. The GPIB data word format is the same for both Options 03 and 03SH (reference Figure 3.27). Table 3.21 provides an input voltage to octal data to binary data conversion. The octal data is displayed on the 6000 readout when the display is enabled. The binary data is outputted from the rear panel Fast A/D or Sample and Hold Fast A/D connector.

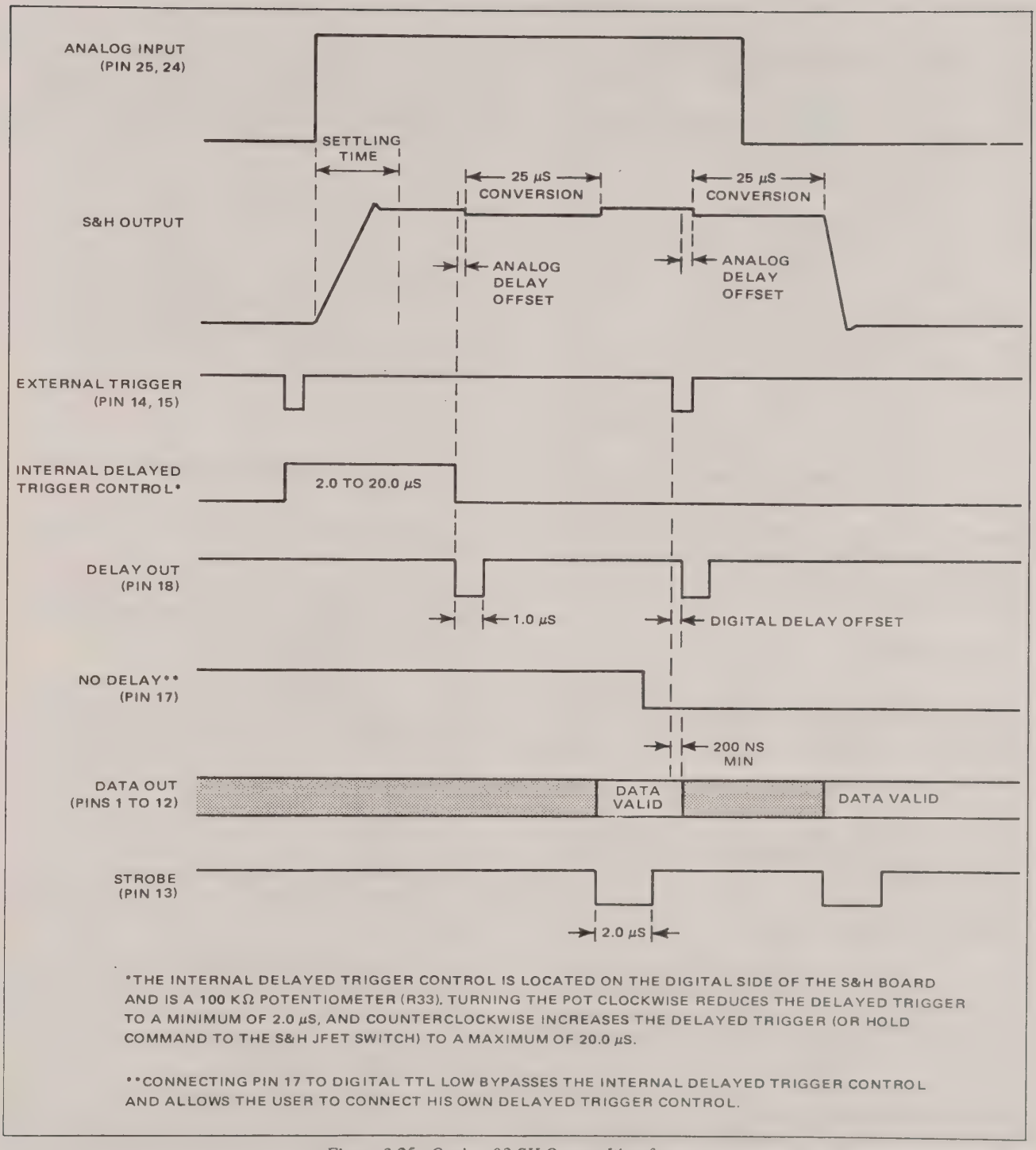


Figure 3.25 - Option 03 SH Output Waveforms

3.6.7 Sample and Hold Fast A/D (Option 03SH).

3.6.7.1 The sample and hold version of the Fast A/D (Option 03SH) may be added to the Model 6000 for applications requiring precise timing of measurements or very short sample times. The sample and hold circuitry increases the data bandwidth of the Fast A/D, and allows for the digitizing of selected portions of input waveforms. Option 03SH also provides an adjustable delay circuit that delays the aperture point to compensate for system settling time. Figure 3.26 shows a programming model of the 03SH converter.

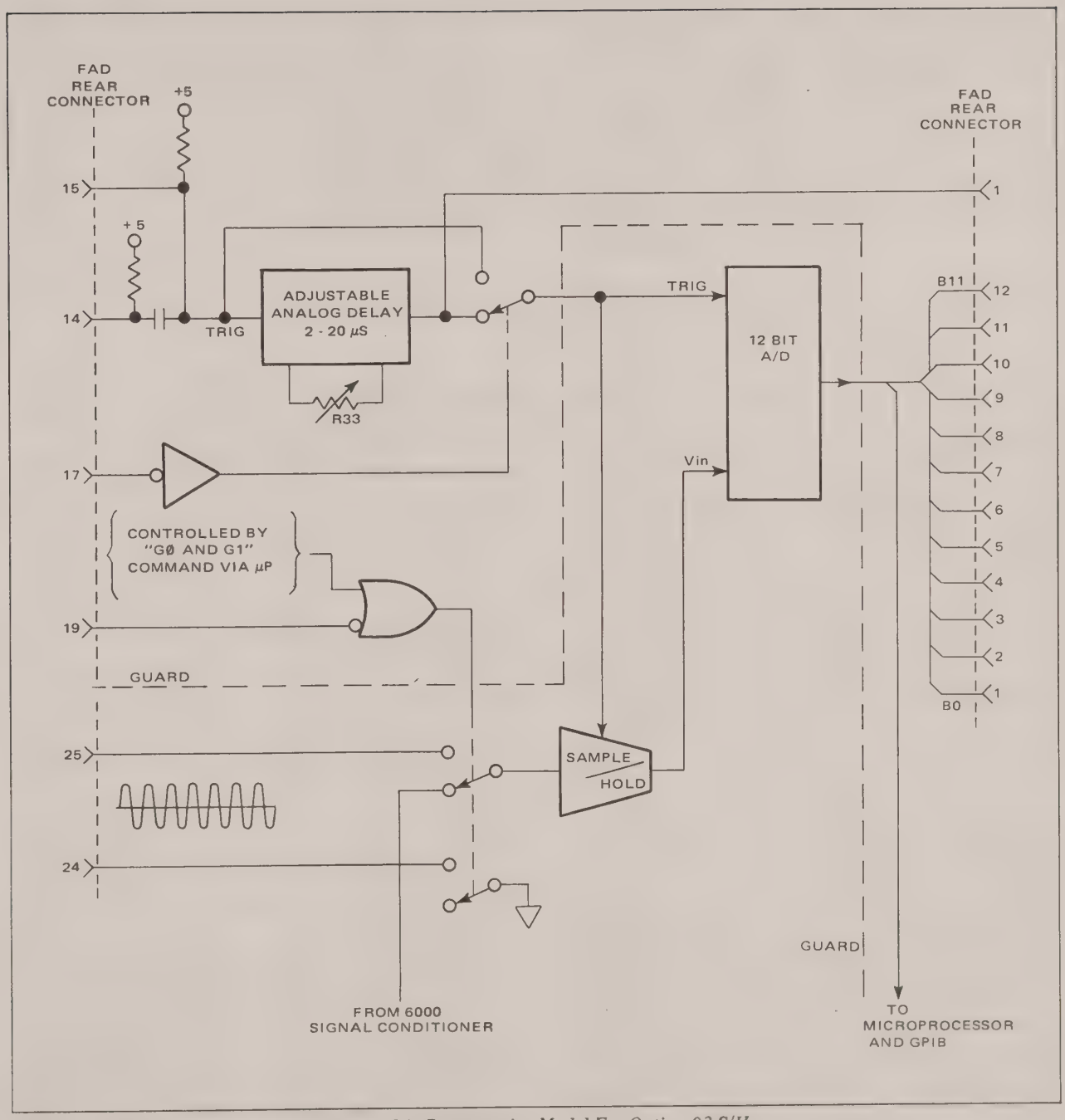


Figure 3.26 - Programming Model For Option 03-S/H

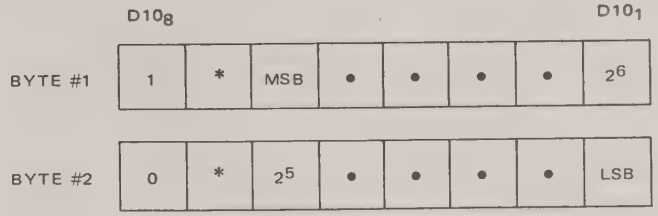


Figure 3.27 - GPIB Data Output Format (Options 03 and 03 SH)

Table 3.21 - Fast A/D Output Data Conversion Reference

NOTE: The scale factor for the Fast A/D is 1 count (octal or binary) per 10mV of input voltage.

Voltage Input	Octal Display*	Binary Output*
−20.480	−3777**	100 000 000 000
−20.470	−3777	100 000 000 001
−20.000	−3720	100 000 110 000
−19.000	−3554	100 010 010 100
−18.000	−3410	100 011 111 000
−17.000	−3244	100 101 011 100
−16.000	−3100	100 111 000 000
−15.000	−2734	101 000 100 100
−14.000	−2570	101 010 001 000
−13.000	−2424	101 011 101 100
−12.000	−2260	101 101 010 000
−11.000	−2114	101 110 110 100
−10.240	−2000	110 000 000 000
−10.000	−1750	110 000 011 000
−9.000	−1604	110 001 111 100
−8.000	−1440	110 011 100 000
−7.000	−1274	110 101 000 100
−6.000	−1130	110 110 101 000
−5.120	−1000	111 000 000 000
−5.000	−0764	111 000 001 100
−4.000	−0620	111 001 110 000
−3.000	−0454	111 011 010 100
−2.500	−0372	111 100 000 110
−2.000	−0310	111 100 111 000
−1.500	−0226	111 101 101 010
−1.000	−0144	111 110 011 100
-0.500	−0062	111 111 001 110
−0.250	−0031	111 111 100 111
−0.010	−0001	111 111 111 111
0.000	0000	000 000 000 000
+0.500	0062	000 000 110 010
+1.000	0144	000 001 100 100
+1.500	0226	000 010 010 110
+2.000	0310	000 011 001 000
+2.500	0372	000 011 111 010
+3.000	0454	000 100 101 100
+4.000	0620	000 110 010 000
+5.000	0764	000 111 110 100
+5.110	1000	001 000 000 000
+6.000	1130	001 001 011 000
+7.000	1274	001 010 111 100
+8.000	1440	001 100 100 000
+9.000	1604	001 110 000 100
+10.000	1750	001 111 101 000
+10.230	2000	010 000 000 000
+11.000	2114	010 001 001 100
+12.000	2260	010 010 110 000
+13.000	2424	010 100 010 100
+14.000	2270	010 101 111 000
+15.000	2734	010 111 011 100
+16.000	3100	011 001 000 000
+17.000	3244	011 010 100 100
+18.000	3410	011 100 001 000
+19.000	3554	011 101 101 100
+20.000	3720	011 111 010 000
+20.470	3777	011 111 111 111

*The 12 bit data output (from the Fast A/D connector or the GPIB connector) is in two's complement. When the output information is displayed, the 12 bit data is presented (on the 6000 display) in signed octal format.

**Display cannot indicate greater than '3777'

3.7 CALIBRATION CHECK-SPECIFICATION VALIDATION

3.7.1 General.

3.7.1.2 This section contains procedures that compare the operation of the instrument against the published specifications found at the front of this manual. It is intended to be used for incoming inspection and as a periodic check to determine if recalibration of the instrument is warranted.

3.7.1.3 The procedures provide sufficient checks to verify proper operation and that the instrument is within the 90 day accuracy limits. Covers of the instrument are not removed for any of the tests. The required ambient temperature of the environment is $23^{o} \pm 5^{o}C$.

3.7.2 Required Equipment.

3.7.2.1 In Table 3.22 is a list of equipment necessary for checking the instrument. The equipment in this table, with the exception of those in the OTHER category, is the same as required for recalibration and is explained in detail in the following paragraphs.

3.7.2.2 The specific types of equipment in the Suggested Equipment column are acceptable for calibration and provided as a guide in selecting suitable equipment; instruments having operating characteristics equal to or better than those indicated may be substituted.

Table 3.22 - Required Equipment

Function	Qty	Item	Minimum Use Specifications	Suggested Equipment
DC	(1)	Saturated Standard Cell Bank (6 cells)	1 ppm, certified	EPPLEY 106
	(2)	DC Voltages Sources	0.1 ppm resolution	FLUKE 332B
	(2)	Voltage Divider, Adjustable	0.1 ppm linearity	FLUKE 720A
	(1)	10:1 Voltage Divider, Fixed	1 ppm, Output Z $\leq$10 Kohms	ESI RV622, With corrections
	(1)	100:1 Voltage Divider, Fixed	1 ppm, Output Z $\leq$10 Kohms	ESI RV622, With corrections
	(2)	Null Detector/μVoltmeters	1 μV sensitivity	FLUKE 845AR
AC	(1)	Thermal Transfer Standard	50 ppm	HOLT 6A, With corrections
	(1)	AC Voltage Source	1 ppm resolution	HP745A/746A
Ω	(8)	Resistance Standards		
		10Ω	10 ppm	ESI SR1 with corrections
		100Ω	5 ppm	ESI SR1 with corrections
		1 KΩ	5 ppm	ESI SR1 with corrections
		10 KΩ	5 ppm	ESI SR1 with corrections
		100 KΩ	5 ppm	ESI SR1 with corrections
		1 MΩ	5 ppm	ESI SR1 with corrections
		10 MΩ	20 ppm	ESI SR1 with corrections
		100 MΩ	80 ppm	Fabricated
OTHER	(1)	Momentary Switch, SPST	–	–
	(2)	1.5 volt cells w/screwtype binding posts	–	–
	(1)	Insulated Adjustment tool	–	JFD5284
	(1)	100Ω, 10 Kilohm, 1 Megohm 1/4 Watt 5% Carbon Resistors	5%	–
	(1)	1 μFD non polar capacitor	–	–
	(1)	100MΩ, metal film resistor of known value	25 ppm	–

3.7.2.3 DC VOLTAGE SOURCES.

3.7.2.3.1 To produce voltage levels of necessary accuracy, special techniques are required. Suitable methods of generating these voltages are shown in Figures 3.28 and 3.29.

3.7.2.3.2 *10 Volt Source.*

3.7.2.3.2.1 A precise and traceable source of 10 volts is required, not only for calibrating the 10 volt range, but also as a reference for generating highly accurate .1, 1, 100, and 1000 volt levels. The 10 volt source used must satisfy the following requirements.

a. It must be traceable to the National Bureau of Standards;

b. It must have a total accuracy of 1.1 ppm;

c. It must have a low output impedance.

3.7.2.3.2.2 A source filling these requirements is shown in Figure 3.28. This circuit consists of a null detector, 7-decade voltage divider, a DC voltage supply, and a bank of saturated standard cells. Two advantages of this particular hookup are that; (a) there is minimal loading of the standard cells and (b) stability, not accuracy, is the primary requirement of the dc voltage supply.

3.7.2.3.2.3 The output of this circuit is set to a precise 10 volts by setting the voltage divider to the value of the standard cells. The DC voltage source is then adjusted to produce a null on the null detector. The accuracy of the 10 volt source is within 1.1 ppm.

3.7.2.3.3 *Other Sources.*

3.7.2.3.3.1 The remainder of the DC sources can be generated by the circuits shown in Figure 3.29. Each of these hookups use a calibrated 10 volt source having the characteristics of the one previously described.

3.7.2.3.4 *Accuracy, DC.*

3.7.2.3.4.1 The accuracy of the DC voltage sources is obtained by adding the various sources of error in each hookup; errors in this discussion are defined in parts per million (ppm). For the 10 volt source, the error is the sum of the standard cell bank (certified at 1 ppm) and the voltage divider (0.1 ppm), giving a constant 1.1 ppm. In Table 3.23 is shown the errors of each voltage source, the total accuracy of each hookup, the accuracy of the Model 6000 DMM, and the degree to which the sources exceed the required accuracy of the DMM (4 to 10 times better is the suggested accuracy ratio per MIL-M-38793).

Table 3.23 - **DC Source Accuracies**

Range	10 Volt Source	Fixed Divider	Total Accuracy	24 hr. DMM Full Scale Accuracy	Times Better
10	1.1 ppm	–	1.1 ppm	10 ppm	9
1	1.1 ppm	1 ppm	2.1 ppm	20 ppm	9.5
100 mV	1.1 ppm	1 ppm	2.1 ppm	70 ppm	33
100	1.1 ppm	1 ppm	2.12 ppm	20 ppm	9.5
1000	1.1 ppm	1 ppm	2.12 ppm	20 ppm	9.5

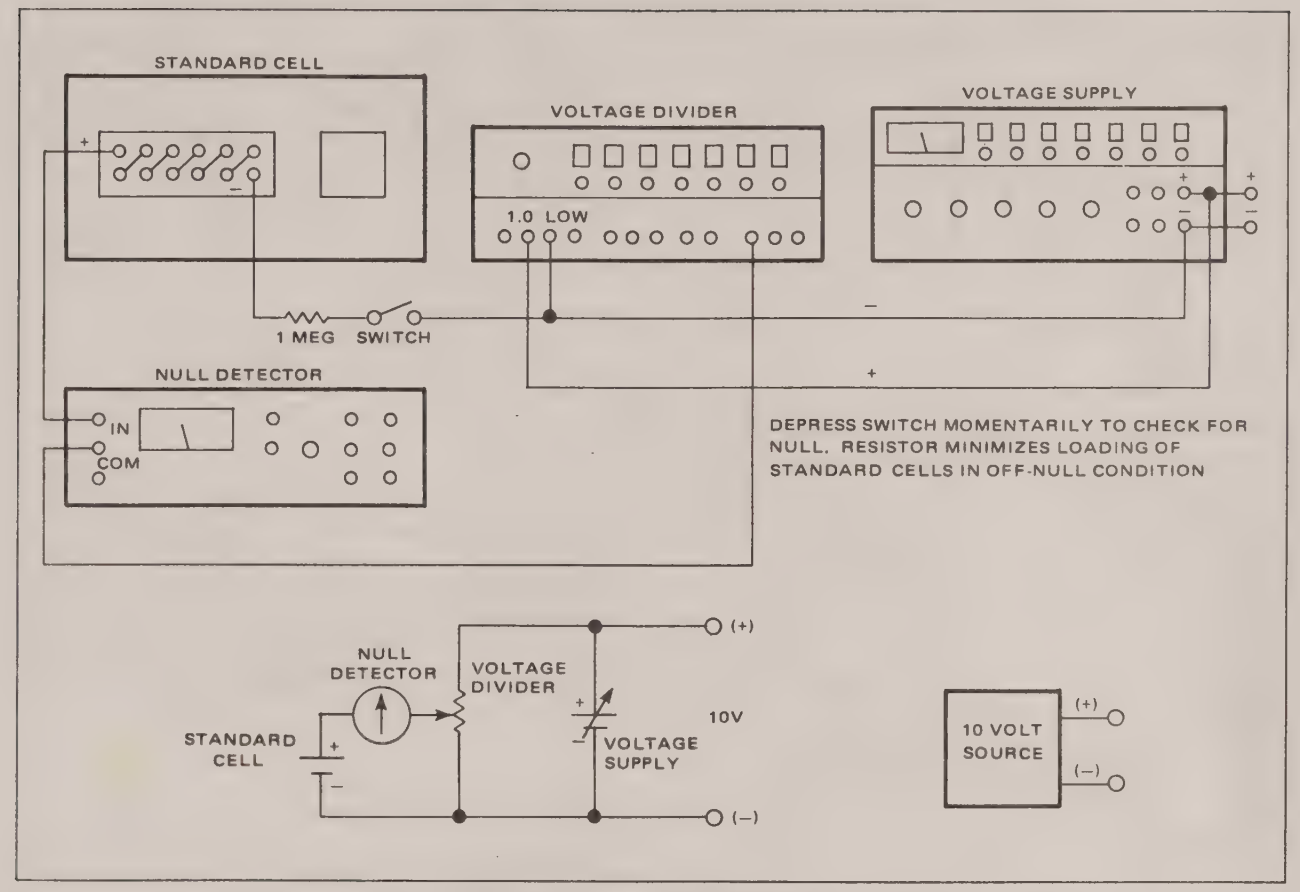


Figure 3.28 - 10 Volt Source

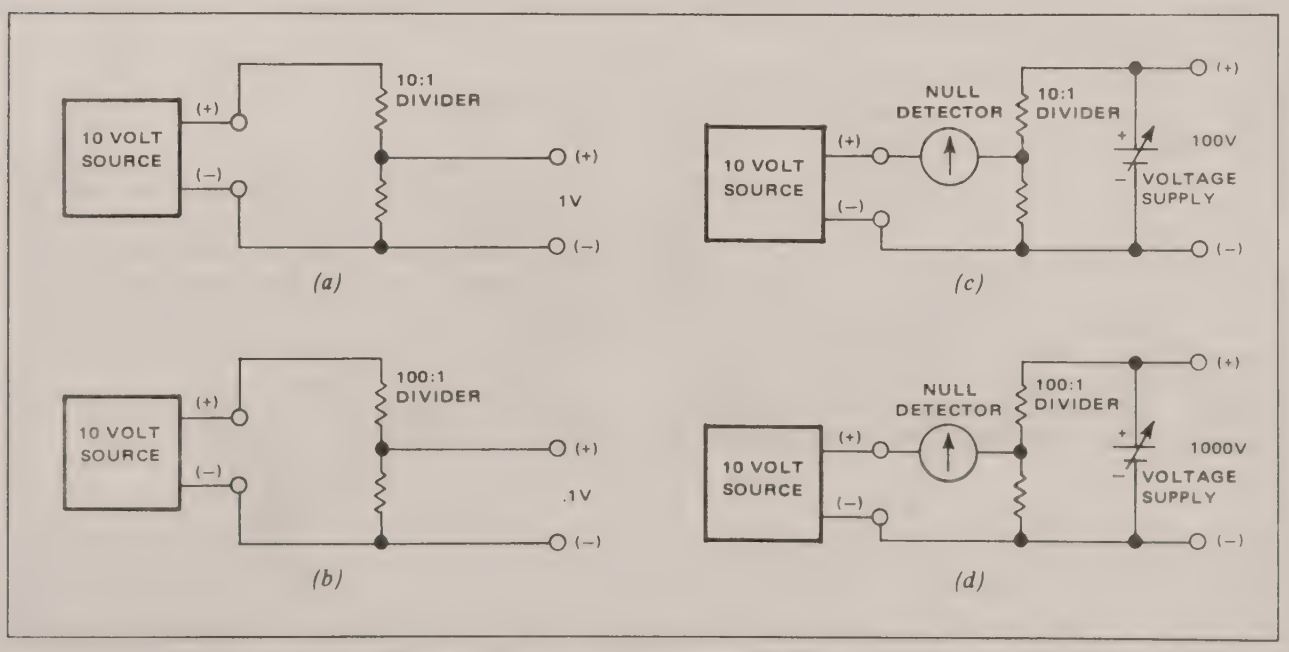
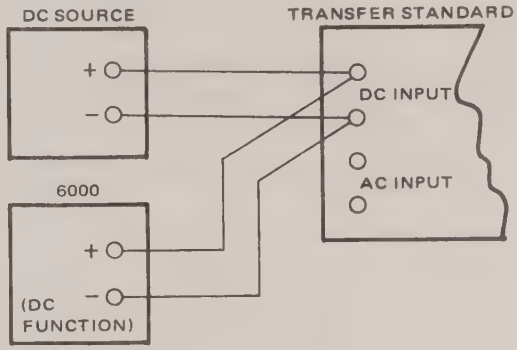
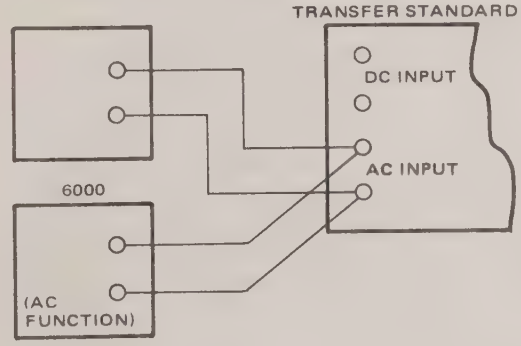


Figure 3.29 - Generating Accurate DC Levels



DC. With DMM used to monitor DC output, DC source is adjusted to desired voltage. Transfer standard is then used per manufacturer instructions.



AC. The ac source is adjusted to produce a null on transfer standard. The AC source output is now calibrated and can be used as a precision source for the recalibration of the 6000 AC Converter. (Option 10)
NOTE: Because of the low input impedance of the transfer standard, the DMM input leads must be connected as close to the transfer standard input terminals as possible.

Figure 3.30 - AC Source

3.7.2.4 AC VOLTAGE SOURCES.

3.7.2.4.1 The generation of accurate ac signals for checking the AC Converter ranges, requires the use of a thermal transfer standard and a precise DC standard as well as a stable AC source. Sufficient accuracy can be obtained by using a DC source and the Model 6000 being tested. The circuitry connections are shown in Figure 3.30. Information on the use of the transfer standard can be obtained from the operators manual accompanying the standard. The 6000 is used to set the DC source to the desired voltage; the thermal transfer standard is then used to calibrate the output of the AC source. The calibrated AC source is used to check the 6000 AC Converter. This procedure is repeated for each range.

Table 3.24 - **AC Source Accuracies**

INPUT		ACCURACY		
AC Source		Thermal Transfer Standard	DC Source	Total AC Source
Volts	Freq			
1, 10, and 100 Volts	400 Hz	35 ppm	10 ppm	45 ppm
	50 kHz	50 ppm		60 ppm
500 Volts	40 kHz	50 ppm		60 ppm
1000 Volts	400 Hz	52 ppm		62 ppm

3.7.2.4.2 *Accuracy, AC.*

3.7.2.4.2.1 The accuracy of the AC source is equal to the sum of the transfer standard accuracy and the accuracy of the DC source. The accuracy of the setup for each range and frequency used is provided in Table 3.24.

3.7.3 Procedure.

3.7.3.1 Allow two hours for warmup. Connect the instrument and the test equipment as shown in the figure supplied with each accuracy check. Select the controls and inputs as called out in the tables and monitor the instrument readout for the indicated values. The specification tests are performed using the front panel input connectors. (Front input is selected by pressing the SHIFT FR keys (ref (24) and (9), Figure 3.2 and Table 3.2) so that the RI annunciator is off (ref (29), Figure 3.1 and Table 3.1).

Table 3.25 - DC Range Check (Low Ranges)

DVM		INPUT SIGNAL		NOMINAL READING (5-1/2 Digit Mode)	TOLERANCE (90 Day Spec)	NOTE
FUNCTION	RANGE	DC VOLTAGE STANDARD	DIVIDER SETTING			
DC	100 mV	10.00000	.01000	100.000	099.992 – 100.008	23°C ± 5°C (After Auto Cal)
	1V	10.00000	.10000	1.00000	0.99997 – 1.00003	

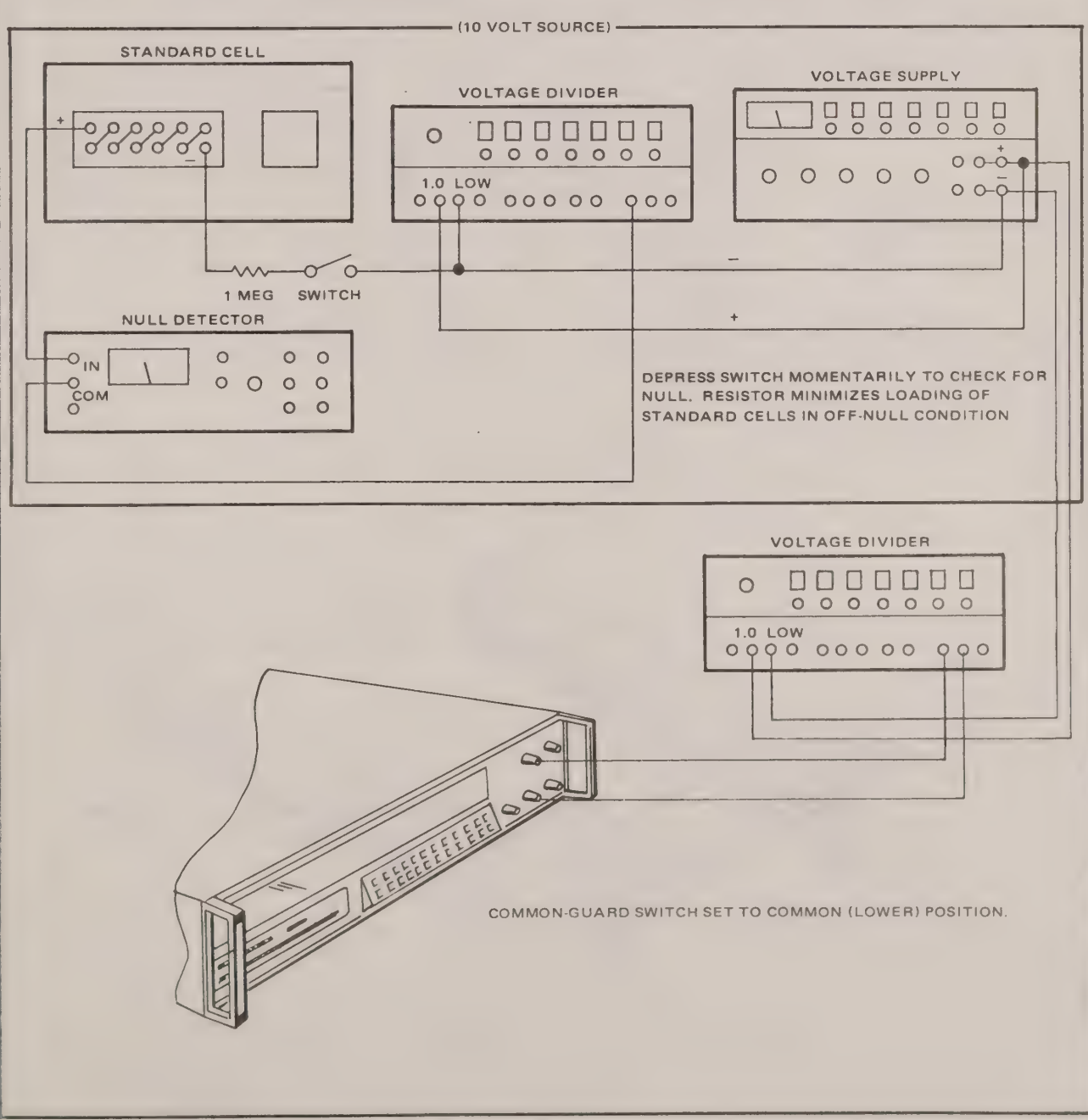
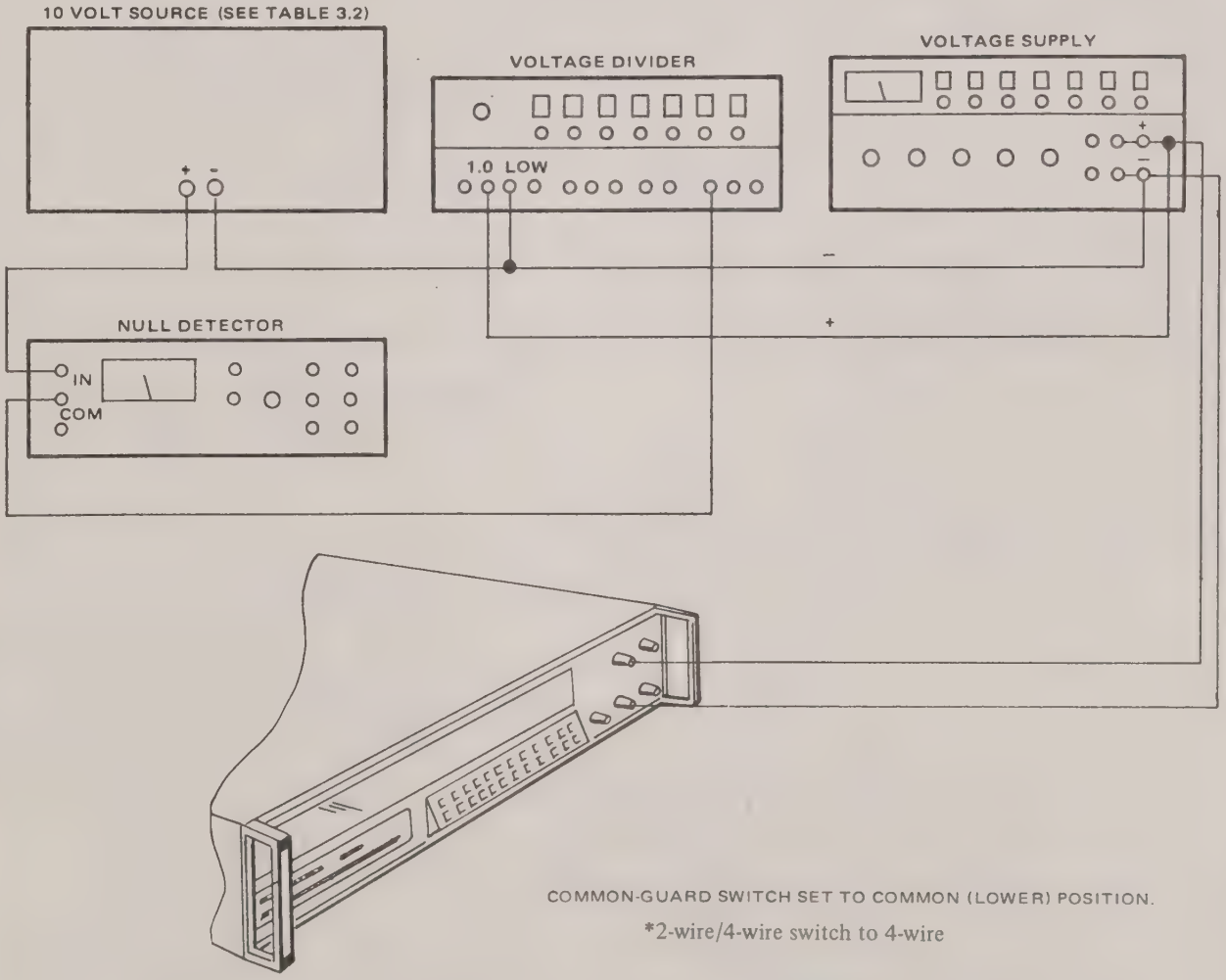


Table 3.26 - **DC Range Check (High Ranges)**

DVM		INPUT SIGNAL		NOMINAL READING (5 1/2 Digit Mode)	TOLERANCE (90 Day Spec)	NOTE
FUNCTION	RANGE	DC VOLTAGE STANDARD				
DC	10	10.0000V		10.0000	9.9998 – 10.0002	23°C ± 5°C (After Auto Cal) *
	100	100.000V		100.000	99.997 – 100.003	
	1000	1000.00V		1000.00	999.97 – 1000.03	



COMMON-GUARD SWITCH SET TO COMMON (LOWER) POSITION.

*2-wire/4-wire switch to 4-wire

Table 3.27 - 4-Wire Ratio Check (Option 34)

DVM		INPUT SIGNAL		NOMINAL READING (5-1/2 Digit Mode)	TOLERANCE (90 Day Spec)	NOTE
FUNCTION	RANGE	DC VOLTAGE STANDARD				
DC	10	+ 1.00000V	Perform Auto Cal	+1.00000	9.9960–1 – 1.00040	23°C ± 5°C (After Auto Cal)
RATIO	10	+10.00000V	Perform Auto Cal	+10.0000	9.9996–1 – 1.00004	
		–10.00000V		+10.0000	9.9996–1 – 1.00004	

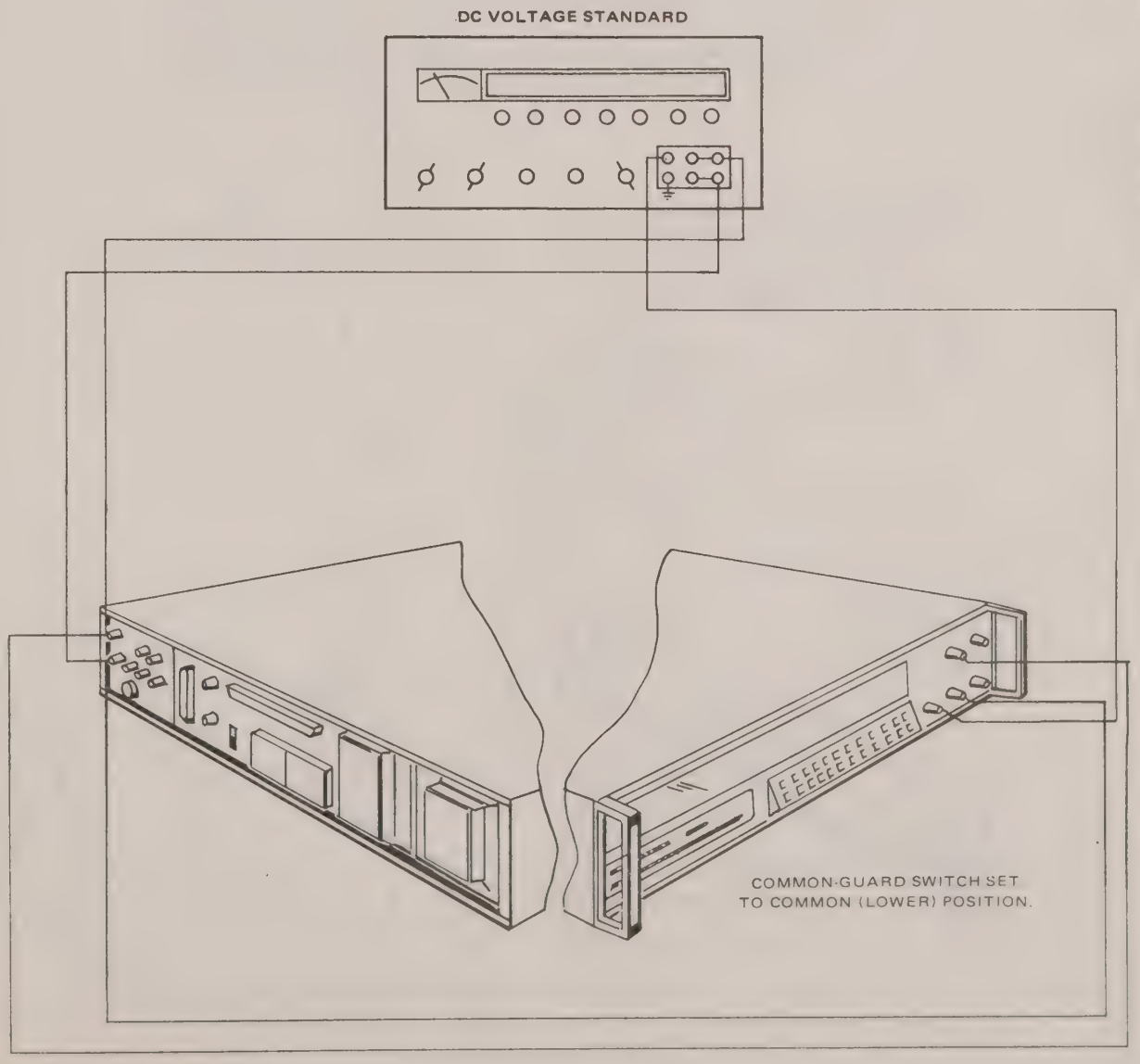


Table 3.28 - RMS AC Converter Range Check (Option 10)

DVM		INPUT SIGNAL		NOMINAL READING (5-1/2 Digit Mode)	TOLERANCE	NOTE (90 Day Spec)
FUNCTION	RANGE	DC VOLTAGE STANDARD	AC			
AC	1	1.000000	1V @ 400 Hz	1.00000	.99870 – 1.00130	23°C ± 5°C (After Auto Cal) *
		1.000000	1V @ 50 kHz	1.00000	.99800 – 1.00200	
	10	10.00000	10V @ 400 Hz	10.0000	9.9870 – 10.0130	
		10.00000	10V @ 50 kHz	10.0000	9.9800 – 10.0200	
	100	100.0000	100V @ 400 Hz	100.000	99.870 – 100.130	
		100.0000	100V @ 50 kHz	100.000	99.800 – 100.200	
	1000	1000.000	1000V @ 400 Hz	1000.00	997.40 – 1002.60	
		500.000	500V @ 40 kHz	500.00	498.50 – 501.50	

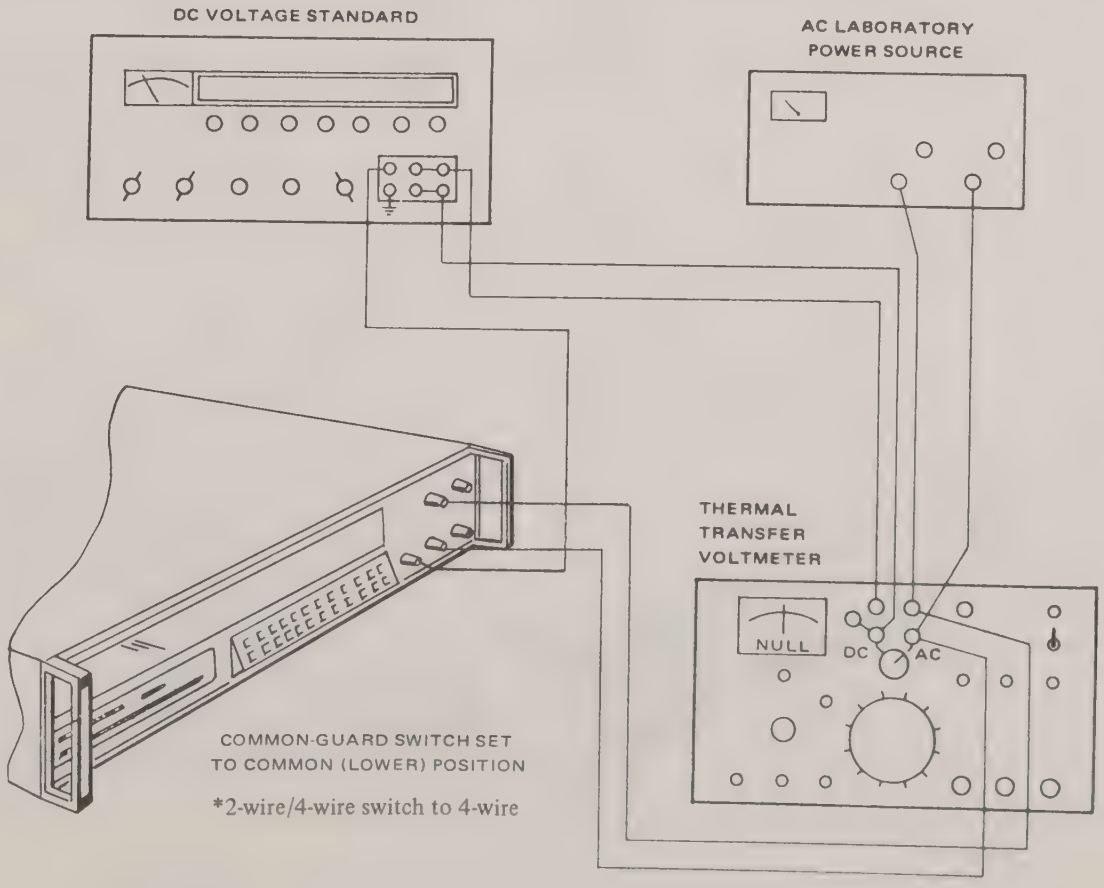


Table 3.29 - AC/AC Ratio Check (Option 11)

DVM		INPUT SIGNAL		NOMINAL READING (5-1/2 Digit Mode)	TOLERANCE	NOTE (90 Day Spec)
FUNCTION	RANGE		AC			
AC HARDWARE RATIO	1		1V @ 400 Hz	1.00000	.99740 – 1.00260	23°C ± 5°C (After Auto Cal)
	10		10V @ 400 Hz	1.00000	.99740 – 1.00260	
	100		100V @ 400 Hz	1.00000	.99740 – 1.00260	
	1000		1000V @ 400 Hz	1.00000	.99540 – 1.00460	

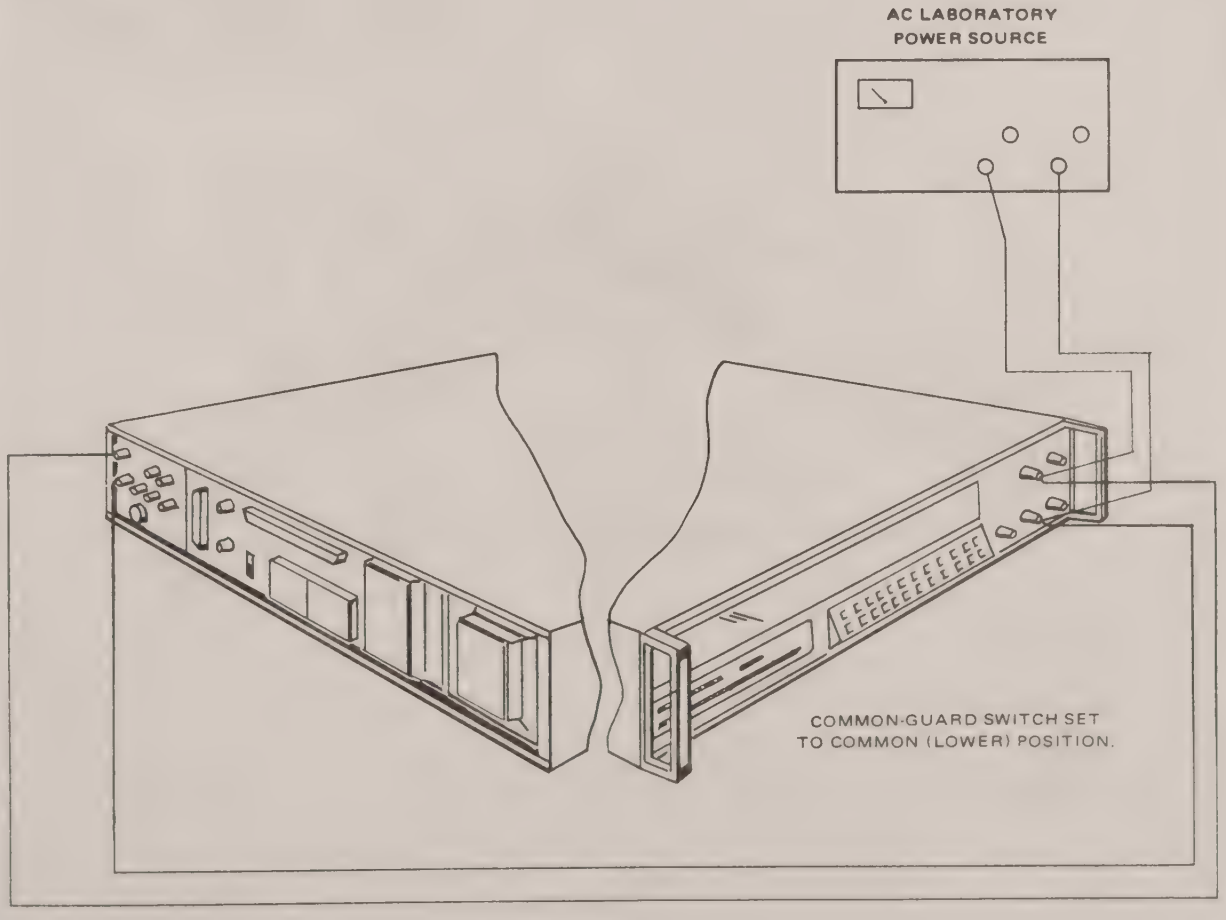


Table 3.30 - Ohms-Megohms Range Check (Options 24 and 41)

DVM		INPUT SIGNAL		NOMINAL READING (5-1/2 Digit Mode)	TOLERANCE* (90 Day Spec)
FUNCTION	RANGE	NOMINAL STANDARD VALUE	STANDARD VALUE KNOWN TO WITHIN:		
Ω - MΩ (Option 24)	10Ω	10Ω	±.001%	10.0000	± 11 digits
	100Ω	100Ω	±.0005%	100.000	± 5 digits
	1 kΩ	1 kΩ	±.0005%	1.00000	± 5 digits
	10 kΩ	10 kΩ	±.0005%	10.0000	± 5 digits
	100 kΩ	100 kΩ	±.0005%	100.000	± 5 digits
	1 MΩ	1 MΩ	±.0005%	1.00000	± 5 digits
	10 MΩ	10 MΩ	±.002%	10.0000	± 33 digits
	100 MΩ	100 MΩ	±.01%	100.000	±51 digits
Ω (Option 24 and 41)	1Ω	1Ω	.002%	1.00000	± 40 digits (see procedure section 3.3.6)

*After Autocal

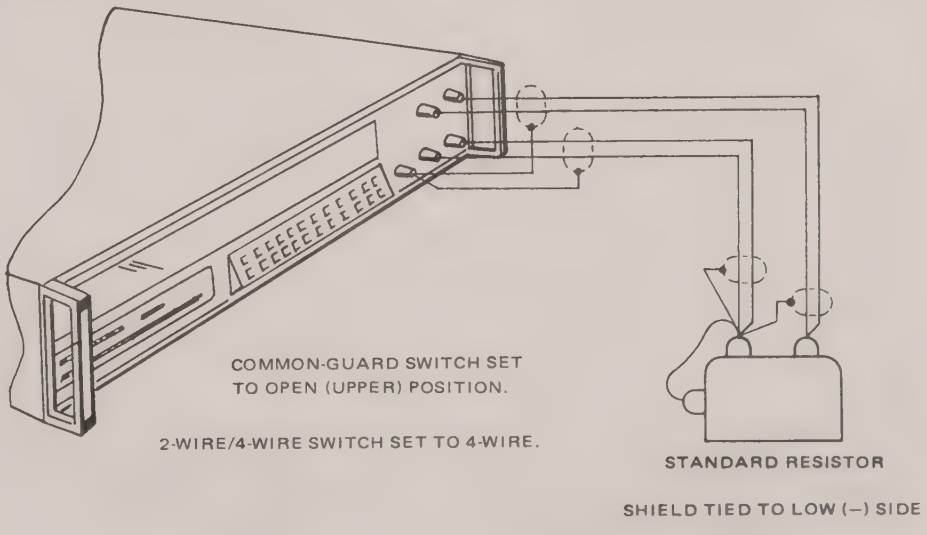

COMMON-GUARD SWITCH SET TO OPEN (UPPER) POSITION.
2-WIRE/4-WIRE SWITCH SET TO 4-WIRE.
STANDARD RESISTOR
SHIELD TIED TO LOW (–) SIDE

Table 3.31 - Common Mode Rejection (In DC Volts Function)

DVM		INPUT SIGNAL		NOMINAL READING (5-1/2 Digit Mode) See Note 1	TOLERANCE	NOTE
FUNCTION	RANGE	S1				
DCV FILT. OUT	100 mV	Off			±1 digit from nominal	1) With switch S-1 in the off position, record the reading displayed on the DMM's readout in the "nominal reading" boxes of the table.
		DC			± 50 digits from nominal	
		AC			±25 digits from nominal	
DCV FILT. IN	100 mV	DC			± 50 digits from nominal	
		AC			± 2.5 digits from nominal	

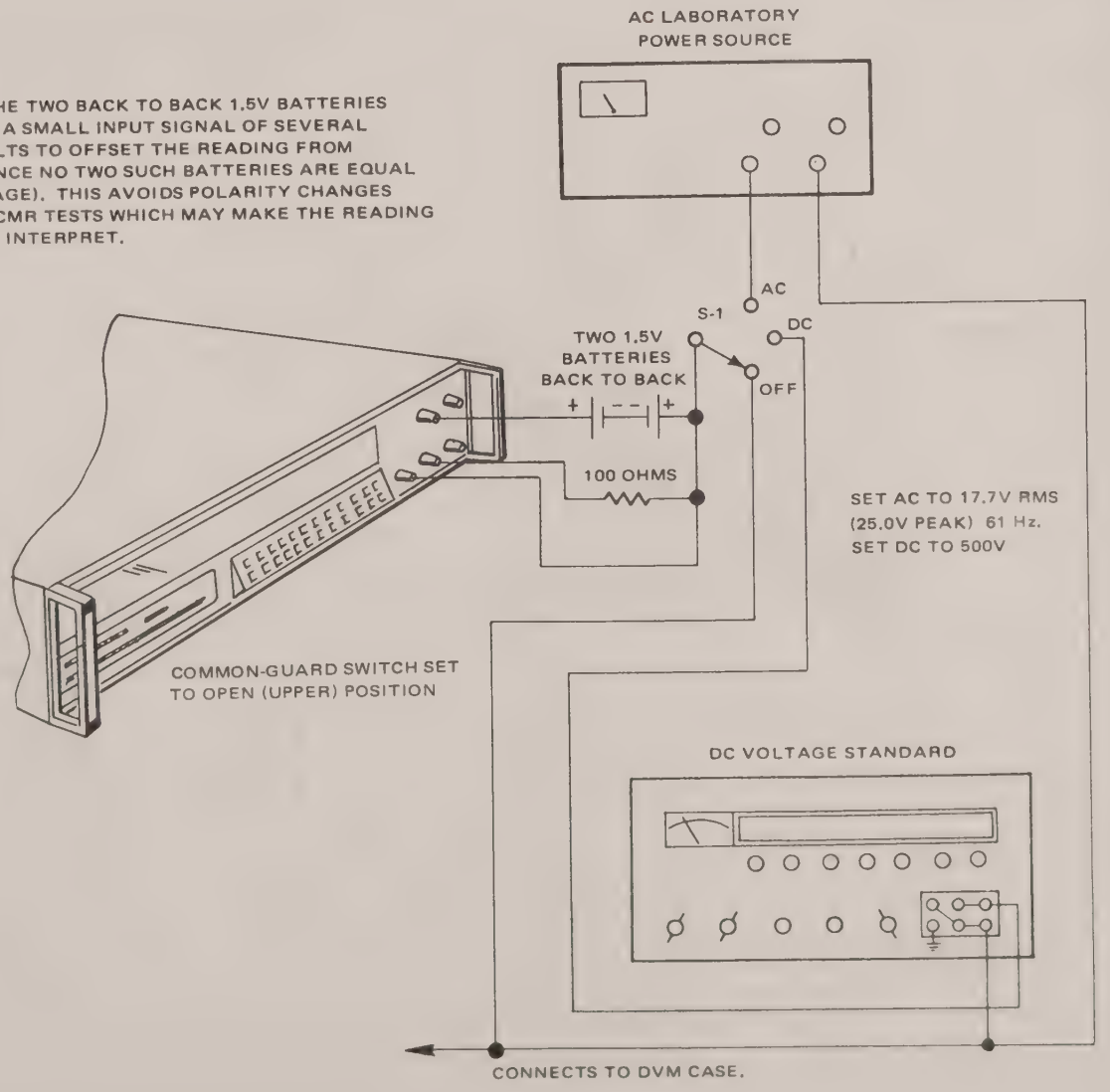

AC LABORATORY POWER SOURCE
NOTE: THE TWO BACK TO BACK 1.5V BATTERIES PROVIDE A SMALL INPUT SIGNAL OF SEVERAL MILLIVOLTS TO OFFSET THE READING FROM ZERO (SINCE NO TWO SUCH BATTERIES ARE EQUAL IN VOLTAGE). THIS AVOIDS POLARITY CHANGES DURING CMR TESTS WHICH MAY MAKE THE READING HARD TO INTERPRET.
AC
S-1
DC
TWO 1.5V BATTERIES BACK TO BACK
OFF
100 OHMS
SET AC TO 17.7V RMS (25.0V PEAK) 61 Hz.
SET DC TO 500V
COMMON-GUARD SWITCH SET TO OPEN (UPPER) POSITION
DC VOLTAGE STANDARD
CONNECTS TO DVM CASE.

Table 3.32 - **Normal Mode Noise Rejection (In DC Volts Function)**

DVM		INPUT SIGNAL		NOMINAL READING (5-1/2 Digit Mode)	TOLERANCE	NOTE
FUNCTION	RANGE	DC	AC			
DC FILT. OUT	10	0.5V	10V*, 60 Hz†	00.5000	±400 digits	
FILT. IN	1V	0.5V	2V*, 60 Hz†	0.50000	± 2 digits	

*peak
†50 Hz (50 Hz Option)

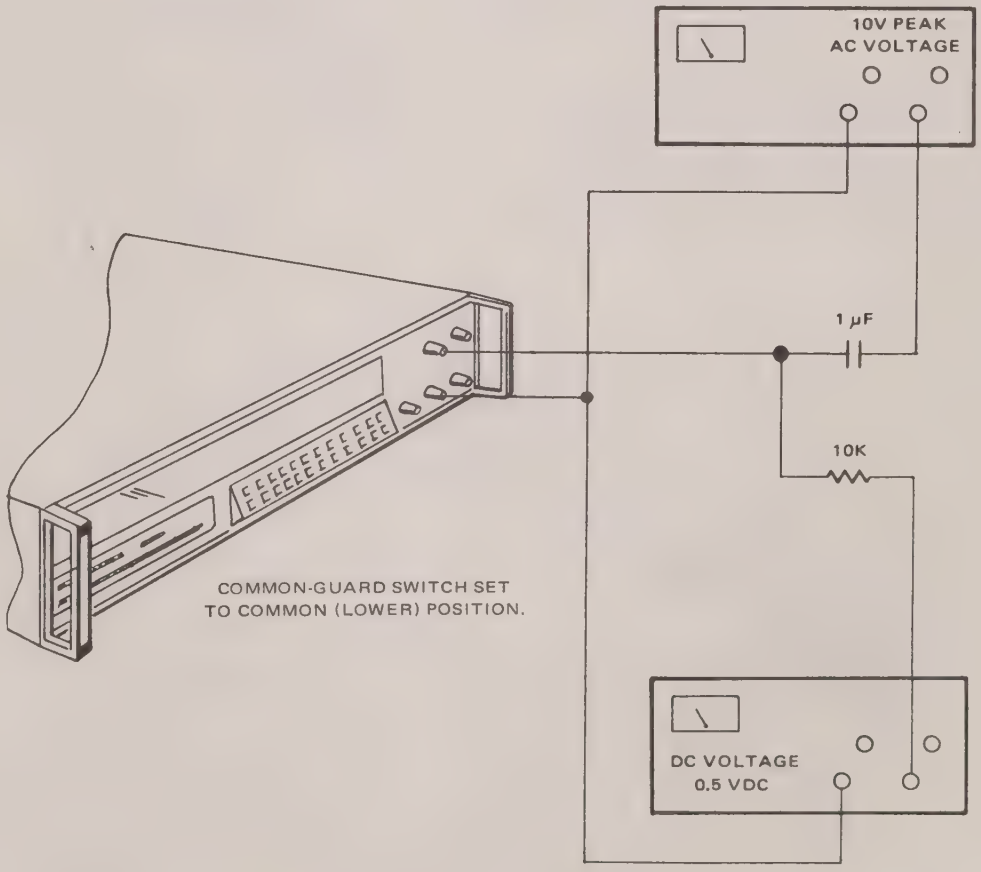
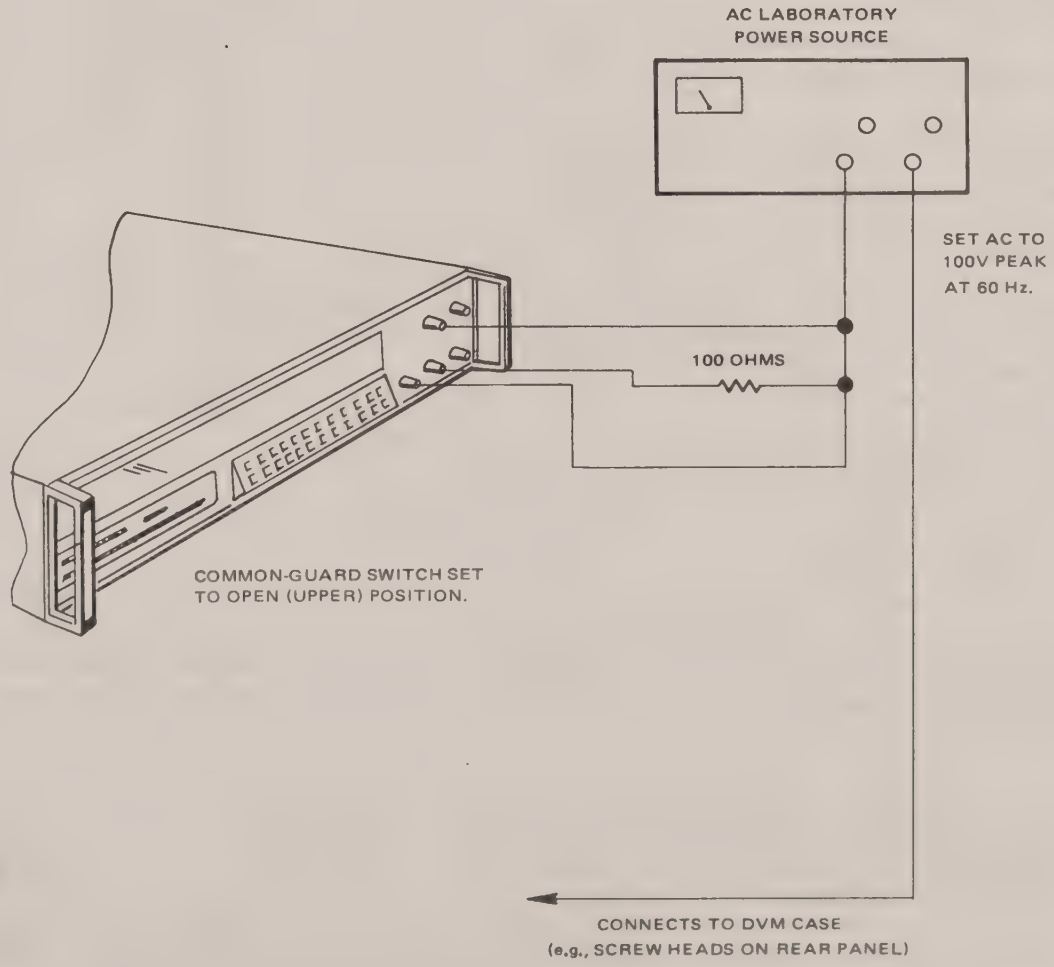


Table 3.33 - **Common Mode Rejection (In AC Volts Function)**

DVM		COMMON MODE INPUT SIGNAL		NOMINAL READING (see note)	TOLERANCE	NOTE
FUNCTION	RANGE	VOLTAGE	FREQ.			
AC	1	100V Peak	60 Hz		±10 digits	Enter reading with shorted input in nominal column before beginning
	10	100V Peak	60 Hz		±1 digit	
	100	100V Peak	60 Hz		±1 digit	
	1000	100V Peak	60 Hz		±1 digit	



3.8 LABORATORY CALIBRATION.

3.8.1 General procedures are presented in this subsection for recalibration of the Series 6000 Exchangeable Cal-Module. The Exchangeable Cal-Module allows a Series 6000 Amplitude Measurement System to be calibrated by exchanging the Calibration Module with a calibrated module, or calibrating the Module in place. If the Module is exchanged, the Module needing calibration can be plugged into another 6000 or a Calibration Test Assembly for calibration. See Table 3.22 for Test Equipment.

3.8.2 Calibration Setup.

3.8.2.1 Remove factory seal protecting Cal Switch, No. 10 on rear panel. Replace seal upon completion of calibration.

3.8.2.2 Apply power to instrument and allow at least 2 hours warmup at an ambient temperature of 23 $\pm$ 1°C, unless otherwise noted.

3.8.2.3 DIGICAL TM DIGITAL CALIBRATION.

3.8.2.3.1 Most of the Model 6000 functions and ranges may be calibrated from the front panel, without removing the covers. Correction factors are stored in non-volatile memory and remain valid even when power is removed from the DMM.

3.8.2.3.2 *Non-Volatile Memory Access.* Access to the Lab-Cal scale factors is provided so that they may be logged and compared with previous scale factors. Entry to non-volatile memory is made as follows:

Step	Key	Display
1	SHIFT	SFT
2	MEM	Contents of memory location 1.

3.8.2.3.3 The contents of succeeding memory locations may be displayed by toggling the UP key. Each press of the key will increment the memory location counter by one. Memory contents are listed in Table 3.33.

3.8.2.4 CALIBRATION TEST ASSEMBLY.

3.8.2.4.1 The Calibration Module may be inserted into a Series 6000 Calibration Test Assembly for calibration and/or troubleshooting. The Calibration Test Assembly electronics are fully compatible with the Model 6000 DMM, but the keyboard and annunciators have been modified to facilitate the calibration process (reference Figure 3.31).

Table 3.34 - Non-Vol Memory Contents

Memory Location	Scale Factor
1	+10 volt reference
2	Preamplifier gain
3	100 mV range gain
4	1 volt range gain
5	−10 volt reference
6	Attenuator −100 volt range
7	Attenuator −1000 volt range
8	1Ω range
9	10Ω range
10	100Ω range
11	1KΩ range
12	10KΩ reference resistor
13	100KΩ range
14	1MΩ range
15	10MΩ range
16	100MΩ range
17	Unused
18	
19	
20	
21	
22	
23	
24	Auto-Cal inhibit bit – Auto-Cal is inhibited if the MSD is a zero and enabled if the MSD is a one.

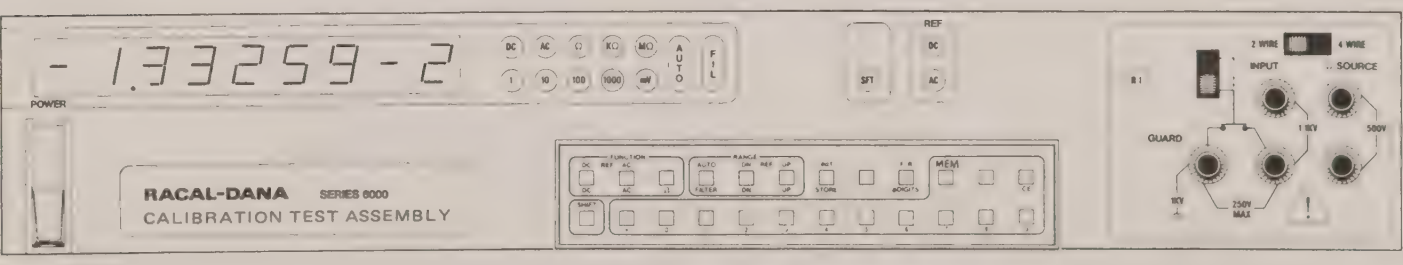


Figure 3.31 - Calibration Test Assembly Front Panel

3.8.3 Inhibiting Automatic Auto-Cal.

3.8.3.1 Automatic Auto-Cal may be temporarily inhibited by either a keyboard command (reference Table 3.2) or upon an instruction received at the systems interface. A more permanent inhibit command (unaffected by power switch cycling) may be entered into non-volatile memory as follows:

a. Perform Step 0 in Table 3.34
b. Press 0 (zero) Key
c. Press STORE Key

3.8.3.2 The Auto-Cal inhibit may be removed as follows:

a. Perform Step 0 in Table 3.34
b. Press 1 Key
c. Press STORE Key

3.8.4 Basic Cal-Module Calibration.

3.8.4.1 The Calibration Module for a basic DC measuring instrument (no options) is calibrated using steps 0-10 in Table 3.34.

3.8.5 Cal-Module Calibration With Options Installed.

3.8.5.1 OHMS (OPTION 24).

3.8.5.1.1 Perform DC and Ohms Calibration (steps 0-21 in Table 3.34).

NOTE

If the 100 mVDC, 1 VDC, 10 VDC and 10 mVDC (if installed) ranges perform within specification, DC calibration is not a prerequisite for Ohms Calibration and can be skipped.

3.8.5.2 TRUE RMS AC VOLTS (OPTION 10).

3.8.5.2.1 Perform DC Calibration (steps 0-10) and AC Calibration (steps 22-27) in Table 3.34.

NOTE

If the 1 VDC range performs within specifications, DC Calibration is not a prerequisite for AC Calibration and can be skipped.

3.8.5.3 AVERAGING AC VOLTS (OPTION 14).

3.8.5.3.1 Perform DC Calibration (steps 0-10) and AC Calibration (steps 22-26 and 28) in Table 3.34.

NOTE

If the 1 VDC range performs within specifications, DC Calibration is not a prerequisite for AC Calibration and can be skipped.

3.8.5.4 DC MILLIVOLTS (OPTION 41).

3.8.5.4.1 Perform DC Calibration (steps 0-10 in Table 3.34).

Table 3.35 - Laboratory Calibration Procedure

Step	Instruction	To Skip a Step	Display	Meaning
0	Move CAL SW ON (up), on Rear Panel # 10. Note: Remove Factory Seal.		Lb CAL 0 Err 33	Go to 1a to Calibrate DC Function. Go to 1b to Skip. Non-Vol. memory will not write.
	DC CALIBRATION			
1a	Press FILTER Key to proceed with DC Calibration		Lb CAL 1	Go to 2
1b	Press DN Key to Skip all DC Calibration		OH CAL 0	DC CAL has been Skipped. Go to 11.
2	Apply −10V IN and press FILTER Key	Not Allowed	Lb CAL 1 Lb CAL 2	Internal Operation Go to 3
3	Apply +10V IN and press FILTER Key	Not Allowed	Lb CAL 2 Lb CAL 3	Internal Operation Go to 4
4	Apply 0.0V IN and press FILTER Key	Not Allowed	dc CAL 5 dc CAL 6 dc CAL 7 dc CAL 8 −1.00XXX (nominal)	Internal Operation Internal Operation Internal Operation Internal Operation if 10 mV Option Installed Normalized Value of −10V Reference Go to 4a
4a	Press FILTER Key	Not Allowed	1.00XXX (nominal)	Normalized Value of +10V Reference Go to 4b
4b	Press FILTER Key	Not Allowed	Lb CAL 4 10 mV Range Lb CAL 4 100 mV Range	Go to 5 if 10 mV Option installed. Go to 6
5	Apply +0.01V IN and press FILTER Key	Press DN Key and go to 6	7.2XXXX−1 (nominal)	Scale Factor - 10 mV Range Go to 5a
5a	Press FILTER Key		Lb CAL 4 100 mV Range	Go to 6

Table 3.35 - Laboratory Calibration Procedure continued

Step	Instruction	To Skip a Step	Display	Meaning
6	Apply +0.10V IN and press FILTER Key	Press DN Key and go to 7	1.XXXXX (nominal)	Scale Factor - 100 mV Range Go to 6a
6a	Press FILTER Key		Lb CAL 4 1V Range	Go to 7
7	Apply +1.0V IN and press FILTER Key	Press DN Key and go to 8	1.XXXXX (nominal)	Scale Factor - 1V Range Go to 7a
7a	Press FILTER Key	———	Lb CAL 4 100V Range	Go to 8
8	Apply +100V IN and press FILTER Key	Press DN Key and go to 9	1.XXXXX (nominal)	Scale Factor - 100V Range Go to 8a
8a	Press FILTER Key	———	Lb CAL 4 1000V Range	Go to 9
9	Apply +1000V IN and press FILTER Key	Press DN Key and go to 10	1.XXXXX (nominal)	Scale Factor - 1000V Range Go to 9a
9a	Press FILTER Key	———	Lb CAL 5 1000V Range	Go to 10
10	Remove +1000V IN	Press DN Key and go to 11 (OH CAL 0) or 22 (AC CAL 0)	Lb CAL 5	Remove 1000V IN before proceeding. Go to 10a
10a	Press FILTER Key		OH CAL 0 AC CAL 0 Lb CAL E	Go to 11 Go to 22 Lab CAL is terminated Go to 10b
10b	Move CAL SW Off (Down)		6000	
	OHMS CALIBRATION			
11			OH CAL 0	Go to 11a to Calibrate Ohms Function. Go to 11b to Skip.
11a	Press FILTER Key to proceed with Ohms Calibration		Lb CAL 6	Go to 12
11b	Press DN Key to Skip all Ohms Calibration		AC CAL 0 Lb CAL E	Ohms CAL has been Skipped. Go to 22. Lab CAL is terminated Go to 21

Table 3.35 - Laboratory Calibration Procedure continued

Step	Instruction	To Skip a Step	Display	Meaning
12	Apply zero ohms in 4-wire connection and press FILTER Key (See Figure 3.29 for connections if 1Ω option installed).	Not Allowed	OH CAL 1 OH CAL 2 OH CAL 3 OH CAL 4 OH CAL 5 OH CAL 6 Lb CAL 7 10 KΩ Range	Internal Operation Internal Operation Internal Operation Internal Operation Internal Operation Internal Operation (if 1Ω option installed) Go to 12a
12a	Apply 10KΩ Std. in 4-wire connection. Enter correction factor for resistance std. (See Note 1) and press STORE Key	Not Allowed	1.0XXXX 1 1 (nominal)	Normalized Value of Internal 10KΩ Ref. Resistor Go to 12b
12b	Press FILTER Key		Lb CAL 7 1Ω Range Lb CAL 7 10Ω Range	Go to 13 if 1Ω option installed. Go to 14
13	Apply 1Ω Std. in 4-wire connection. Enter correction factor for resistance std. (See Note 1) and press STORE Key	Press DN Key and go to 14	1.XXXXX 1 (nominal)	Scale Factor - 1Ω Range Go to 13a
13a	Press FILTER Key		Lb CAL 7 10Ω Range	Go to 14
14	Apply 10Ω Std. in 4-wire connection. Enter correction factor for resistance std. (See Note 1) and press STORE Key	Press DN Key and go to 15	–1.XXXXX 1 (nominal)	Scale Factor - 10Ω Range Go to 14a
14a	Press FILTER Key		Lb CAL 7 100Ω Range	Go to 15
15	Apply 100Ω Std. in 4-wire connection. Enter correction factor for resistance std. (See Note 1) and press STORE Key	Press DN Key and go to 16	–1.XXXXX 1 (nominal)	Scale Factor - 100Ω Range Go to 15a
15a	Press FILTER Key		Lb CAL 7 1 KΩ Range	Go to 16
16	Apply 1KΩ Std. in 4-wire connection. Enter correction factor for resistance std. (See Note 1) and press STORE Key	Press DN Key and go to 17	–1.XXXXX 1 (nominal)	Scale Factor - 1 KΩ Range Go to 16a
16a	Press FILTER Key		Lb CAL 7 100 KΩ Range	Go to 17

Table 3.35 - Laboratory Calibration Procedure continued

Step	Instruction	To Skip a Step	Display	Meaning
17	Apply 100KΩ Std. in 4-wire connection. Enter correction factor for resistance std. (See Note 1) and press STORE Key	Press DN Key and go to 18	1.XXXXX 1 (nominal)	Scale Factor - 100 KΩ Range Go to 17a
17a	Press FILTER Key		Lb CAL 7 1 MΩ Range	Go to 18
18	Apply 1MΩ Std. in 4-wire connection. Enter correction factor for resistance std. (See Note 1) and press STORE Key	Press DN Key and go to 19	1.XXXXX 1 (nominal)	Scale Factor - 1 MΩ Range Go to 18a
18a	Press FILTER Key		Lb CAL 7 10 MΩ Range	Go to 19
19	Apply 10MΩ Std. in 4-wire connection. Enter correction factor for resistance std. (See Note 1) and press STORE Key	Press DN Key and go to 20	1.XXXXX 1 (nominal)	Scale Factor - 10 MΩ Range Go to 19a
19a	Press FILTER Key		Lb CAL 7 100 MΩ Range	Go to 20
20	Apply 100MΩ Std. in 4-wire connection. Enter correction factor for resistance std. (See Note 1) and press STORE Key	Press DN Key and go to 20a	1.XXXXX 1 (nominal)	Scale Factor - 100 MΩ Range Go to 20a
20a	Press FILTER Key		Lb CAL E AC CAL 0	Lab CAL is terminated Go to 21 Go to 22
21	Move CAL SW OFF (Down)		6000	

Note 1 - Correction Factor = $\frac{\text{Actual Value of Std}}{\text{Theoretical Value of Std}}$

e.g. $\frac{99.9983\ K\Omega}{100\ K\Omega} = .99998$

or

$\frac{10.0003\ K\Omega}{10\ K\Omega} = 1.00003$

Table 3.35 - Laboratory Calibration Procedure continued

Step	Instruction	Display	Meaning
	AC CALIBRATION		
22		AC CAL 0	Go to 23 to skip all AC calibration Go to 24 to prepare software for AC converter calibration.
23	Press DN Key	Lb CAL E	AC calibration steps have been skipped. Go to 26.
24	Press FILTER Key	Lb CAL 8	Go to 25.
25	Press FILTER Key	Lb CAL E	Software is prepared for AC converter calibration. Go to 26.
26	Move CAL SW OFF (Down)	6000	Calibration is complete unless AC board calibration has not been performed. To calibrate RMS Converter go to 27. To calibrate Averaging Converter go to 28.
27	RMS Converter Calibration		
27a	Install calibration cover on Calibration Module and allow at least 30 minutes warm-up.		
27b	Select DC Coupled AC (depress AC and DC keys simultaneously) and 1 VAC Range. Connect jumper across input terminals.		
27c	Connect a 10 KΩ resistor in series with + microvoltmeter lead for all the following measurements.		
27d	Connect microvoltmeter to TP3 (+) and TP1 (–). Adjust R71 for microvoltmeter reading of zero ± 30 μV. Remove microvoltmeter + lead from TP3. Turn R53 fully CCW. NOTE: Microvoltmeter negative lead remains connected to TP1 for all measurements.		
27e	Connect + microvoltmeter lead to TP2. Adjust R54 for microvoltmeter reading of +20 μV ± 10 μV.		
27f	Connect + microvoltmeter lead to TP5. Adjust R63 for microvoltmeter reading of zero ± 30 μV.		

Table 3.35 - Laboratory Calibration Procedure continued

27g	Connect + microvoltmeter lead to TP4. Adjust R62 for zero ± 30 mV.
27h	Connect + microvoltmeter lead to TP2. Adjust R53 clockwise for a microvoltmeter reading of zero ± 5 μV.
27i	Remove microvoltmeter leads.
27j	Apply –1.000---VDC to input and note display reading.
27k	Apply +1.000- - -VDC and adjust R55 to obtain the same reading as in 27k. Repeat steps j and k until the two readings are within 10 digits (.01%) of each other.
27l	Apply –0.100- - -VDC to DVM input directly from DC Calibrator (do not use an attenuator) and note display reading.
27m	Apply +0.100- - -VDC and adjust R62 until reading agrees within ± 5 digits of step l.
27n	Remove DC Calibrator from input. .
27o	If the remaining adjustments are performed with the instrument top cover removed. optimum accuracy will not be achieved. Best accuracy will result from installing top cover and allowing at least 30 minutes for internal temperature to stabilize. Perform adjustments by lifting the edge of the cover just long enough to perform each adjustment.
27p	Select AC mode, 1.0V Range. Apply .1 VAC, 500 Hz and adjust R73 for display reading of 0.10000.
27q	Apply 1.0 VAC, 500 Hz and adjust R45 for display reading of 1.00000. Repeat steps p and q until both readings are correct.
27r	Calibrate the 1000V and 1V ranges according to the following table. Range / Input / Frequency / Adjustment 1000V / 500 VAC / 500 Hz / R67 (500V LF) 1000V / 500 VAC / 30 kHz / C27 (500V HF) 1V / 1 VAC / 40 kHz / C28 (1V HF)
27s	Perform step t only if major repairs have been performed on the RMS converter. Otherwise proceed to step v.
27t	Apply a calibrated 1.0V rms pulse train with a crest factor of 7 and a period of 1 millisecond (1 KHz repetition rate). Adjust R52 for a readout of 1.00000 ± 10 digits.

Table 3.35 - Laboratory Calibration Procedure continued

27u	Repeat steps p, q and t until all readings are correct.
27v	Calibrate 1, 10, and 100V ranges according to the following table. Range / Input / Frequency / Adjustment 10V / 10 VAC / 500 Hz / R65 (10V LF) 100V / 100 VAC / 500 Hz / R64 (100V LF) 1V / 1 VAC / 40 kHz / C28, if necessary (1V LF) 10V / 10 VAC / 40 kHz / C24 (10V HF) 100V / 100 VAC / 40 kHz / C23 (100V HF)
27w	Repeat step p.
27x	Perform 5 1/2 digit Auto-Cal (#Digits, 5).
28	Averaging Converter Calibration.
28a	Remove Scaling Amplifier from J304 and install a Scaling Amplifier Bypass board (411628) in its place. Install AC Converter PCB on an extender board.
28b	Select AC function (any range) and leave input terminals open.
28c	Connect the – microvoltmeter lead to TP2. Connect the + microvoltmeter lead through a 10KΩ series resistor to TP5. Adjust R40 for a microvoltmeter reading of zero ± 10 μV.
28d	Connect the + microvoltmeter lead alternately between TP1 and TP3. Adjust R46 so that the voltage readings are balanced within 10 μV of each other and the voltage at each point is zero ± 20 μV.
28e	Remove microvoltmeter leads.
28f	Apply 1.0 VAC at 1 KHz to the input terminals and record the readout. Change the input to 1.0 VAC at 100 KHz. Adjust C13 until the readout is within ± 10 digits of the recorded value (5 1/2 digit mode).
28g	Remove voltage from input terminals. Remove AC Converter PCB from extender board. Install AC Converter in J303.

Table 3.35 - Laboratory Calibration Procedure continued

28h	Remove Scaling Amplifier Bypass board and install Scaling Amplifier in J304. Install the calibration cover on the Calibration Module and allow one hour for warmup.
28i	Select AC function, 1V range. Perform 5 1/2 digit Auto-Cal (#DIGITS, 5) and verify that AC CAL 1 and AC CAL 2 do not appear.
28j	Connect the AC Calibrator to the input terminals and apply 10 mV at 1 KHz. Adjust R50 on the AC Converter PCB for a readout of .01000V.
28k	Apply 1.0V at 1 KHz and adjust R39 (1V LF) on the Scaling Amplifier for a readout of 1.00000V ± 2 digits.
28l	Repeat steps j and k as required.
28m	Set C42 to the center of its span and then calibrate the 1V, 10V, 100V and 1000V ranges according to the following table: Range / Input / Frequency / Adjustment 10V / 10 VAC / 1 KHz / R31 (10V LF) 100V / 100 VAC / 1 KHz / R30 (100V LF) 1000V / 1000 VAC / 1 KHz / R29 (1KV LF) 1000V / 500 VAC / 40 KHz / C36 (500V HF) 1V / 1 VAC / 100 KHz / C40 (1V HF) 10V / 10 VAC / 100 KHz / C28 (10V HF) 100V / 100 VAC / 100 KHz / C27 (100V HF)
28n	Perform 5 1/2 digit Auto-Cal (#Digits, 5).

Note: Replace seal over Cal Switch upon completion of calibration.

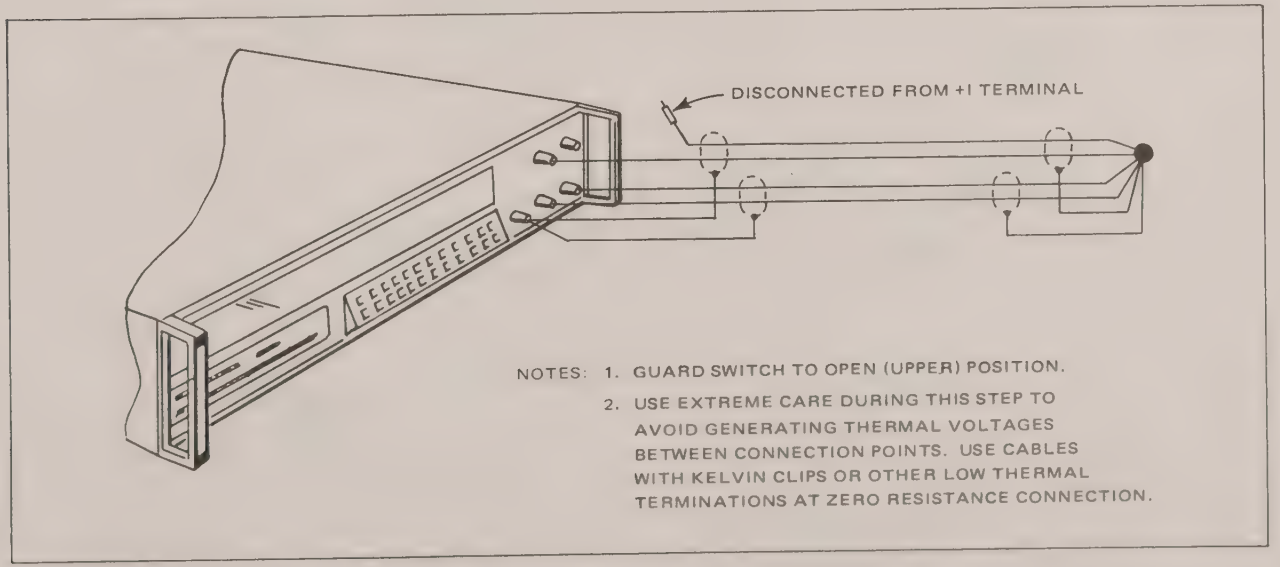
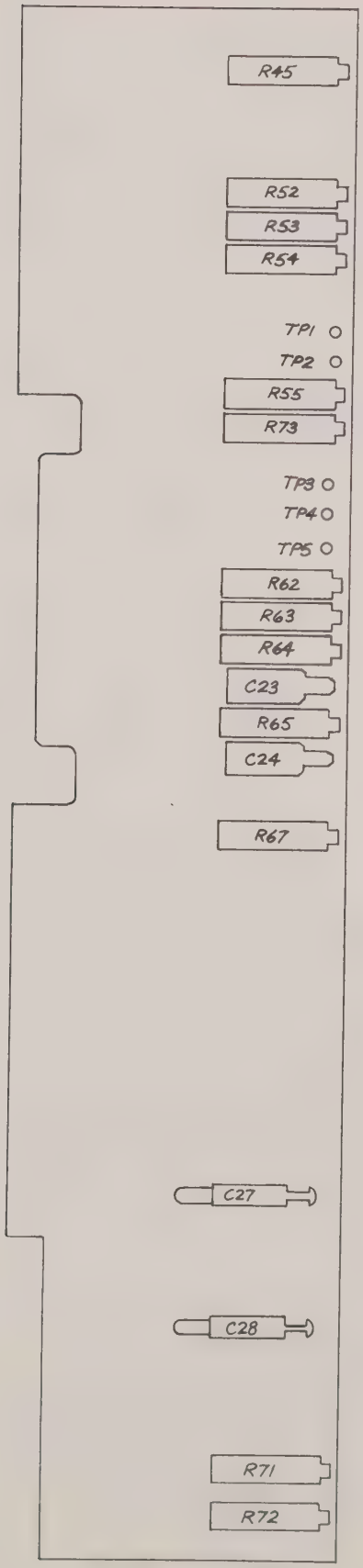
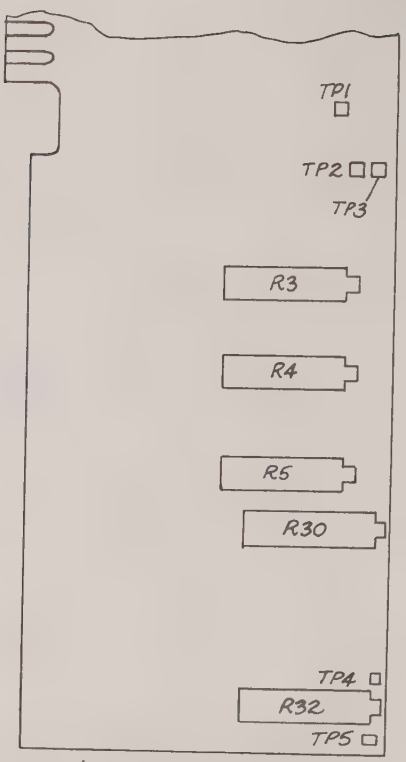

DISCONNECTED FROM +I TERMINAL
NOTES: 1. GUARD SWITCH TO OPEN (UPPER) POSITION.
2. USE EXTREME CARE DURING THIS STEP TO AVOID GENERATING THERMAL VOLTAGES BETWEEN CONNECTION POINTS. USE CABLES WITH KELVIN CLIPS OR OTHER LOW THERMAL TERMINATIONS AT ZERO RESISTANCE CONNECTION.

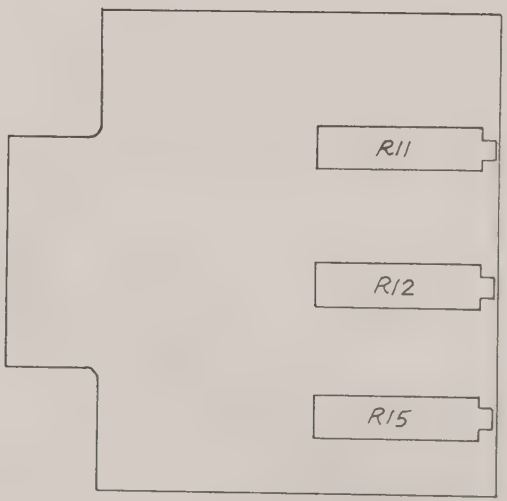
Figure 3.32 - Zero Ohms Connection For DMM's With 1 Ohm Range



RMS Converter PCB
401618

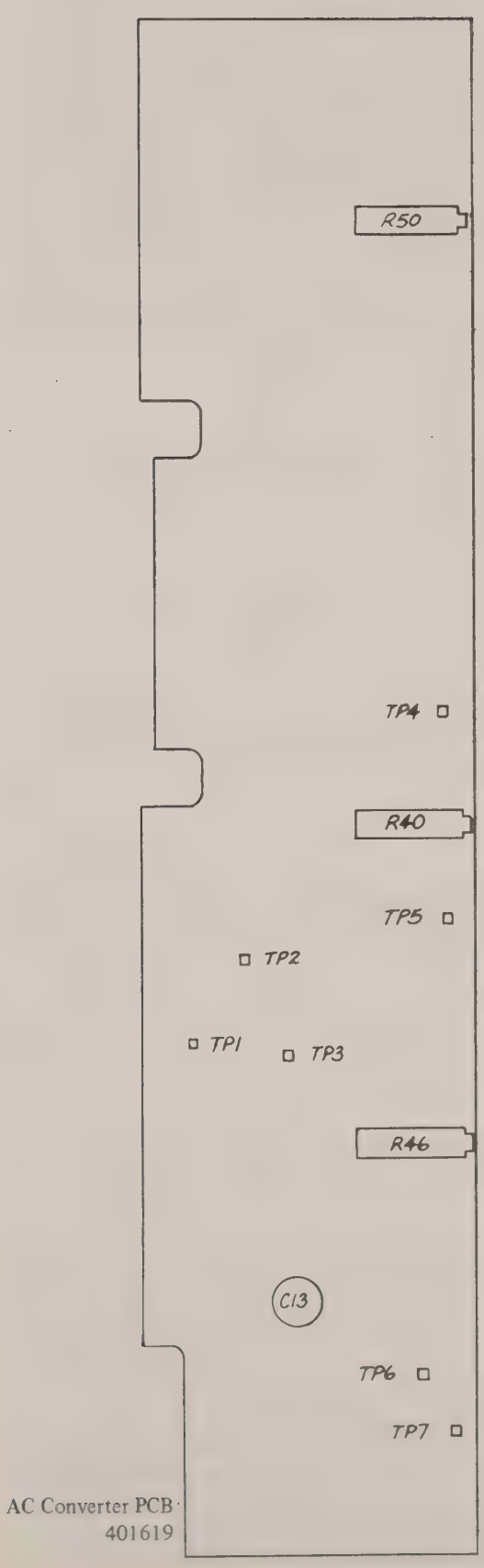


Attenuator Reference PCB
401608



4-Wire Ratio PCB
401626

Figure 3.33 - Calibration Adjustment Locations



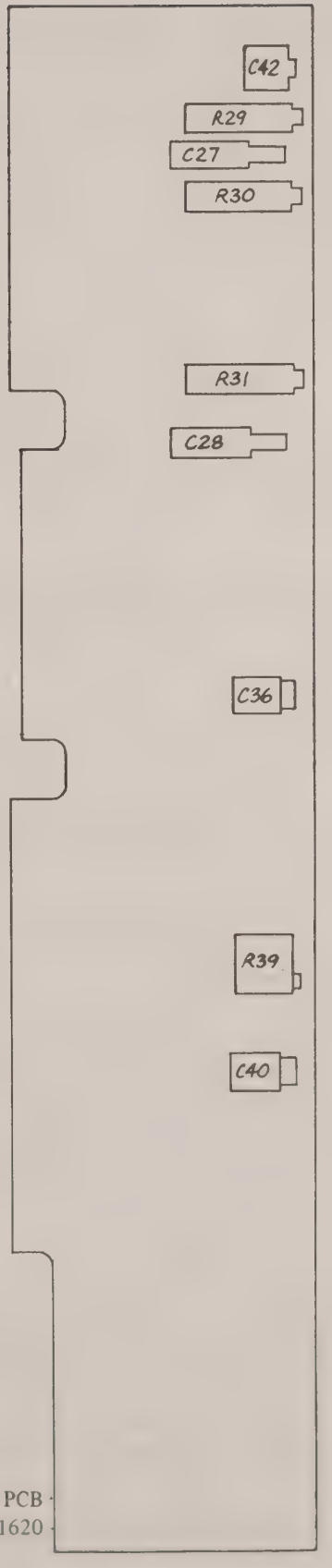


Figure 3.33 - Calibration Adjustment Locations continued

3.8.5.5 4-WIRE RATIO (OPTION 34).

a. The following equipment is required in addition to the items listed in Table 3.22.

1. 5 1/2 Digit DVM with ± .001% F.S. accuracy on 10 VDC range, e.g., Racal-Dana 6000 or 5900.

2. 410764 AC Ratio Bypass/4-Wire DC Ratio Bypass card (2 required).

b. Perform Internal Reference Adjustments given in paragraph 3.8.6.

CAUTION

Adjustment of internal reference voltages per paragraph 3.8.6 will invalidate any previous calibration of the instrument. These adjustments, if needed, must be performed prior to other calibrations.

c. Install a 4-Wire Ratio board in J305 and a Ratio Switching board in J306. Install the calibration cover on the Calibration Module and allow at least one hour warmup.

d. Select DC External Reference (SHIFT, HDW, DC). Verify that (DC) REF annunciator light is ON.

e. Connect a DC Voltage Calibrator to the EXT REF terminals. Connect a jumper from positive terminal of EXT REF input to –INPUT terminal on front panel.

f. Connect the 5 1/2 Digit test DVM (positive lead) to TP2 on the Attenuator/Reference board, and the negative lead to Gnd pin on Motherboard (near Non-Volatile Memory PCB bracket).

g. Apply +1.00000 VDC to EXT REF input from DC Voltage Calibrator. Adjust R12 on 4-Wire Ratio board for +1.00000V on test DVM set to 1.0V range.

h. Increase EXT REF input to 10.0000 VDC. Adjust R11 on 4-Wire Ratio board for +10.0000V on test DVM set to 10V range.

i. Repeat steps g and h as required.

j. Remove jumper from positive terminal of EXT REF input and connect to minus terminal of EXT REF input (other end remains connected to –INPUT).

k. Verify that DC Voltage Calibrator is set to 10.0000 VDC. Adjust R15 on 4-Wire Ratio Board for +10.0000V on test DVM.

l. Decrease EXT REF input to 1.00000 VDC and verify a +1.0000V reading on test DVM set to 10 VDC range.

m. Remove test DVM.

n. Perform DC Calibration using steps 0-10 in Table 3.34.

o. Set 6000 to 10 VDC range and select DC External Reference (SHIFT, HDW, DC). Apply +10.0000 VDC to front panel INPUT and EXT REF input from the same Calibrator. Select 5 1/2 digit Auto-Cal (#DIG., 5) and verify a display reading of 1.00000 ± 2 digits.

p. Reduce calibrator voltage to +1.0000 VDC and select 5 1/2 digit Auto-Cal (# DIG., 5). Verify a display reading of 1.00000 ± 20 digits.

3.8.5.6 AC RATIO (OPTION 11).

a. See 3.8.5.5.a for test equipment requirements.

b. Perform Internal Reference Adjustments given in paragraph 3.8.6.

CAUTION

Adjustment of internal reference voltages per paragraph 3.8.6 will invalidate any previous calibration of the instrument. These adjustments, if needed, must be performed prior to other calibrations.

c. Remove the bypass board and install the Ratio Switching board in J306. Install the calibration cover on the Calibration Module and allow at least one hour warmup.

d. Select DC Coupled AC External Reference range as follows:

1. Press SHIFT Key

2. Press HDW Key

3. Press AC and DC Keys simultaneously

4. Verify that (AC) REF and (DC) REF annunciator lights are ON.

e. Select 1V External Reference Range as follows:

1. Press SHIFT Key

2. Press DN Key and note which Range annunciator light is ON while holding DN key depressed. Repeat SHIFT, DN commands until 1V annunciator light is ON while holding DN key depressed.

f. Connect a jumper between EXT REF terminals.

g. Connect a 10KΩ resistor in series with + microvoltmeter lead for all the following measurements. All adjustments are on the REF RMS Converter Card.

h. Connect positive microvoltmeter to TP3 and negative lead to TP1. Adjust R71 for microvoltmeter reading of zero ± 30 μV. Remove microvoltmeter + lead from TP3. Turn R53 fully CCW.

NOTE

Microvoltmeter negative lead remains connected to TP1 for all measurements.

i. Connect + microvoltmeter lead to TP2. Adjust R54 for microvoltmeter reading of +20μV ± 10μV.

j. Connect + microvoltmeter lead to TP5. Adjust R63 for microvoltmeter reading of zero ± 30 μV.

k. Connect + microvoltmeter lead to TP4. Adjust R62 for zero ± 30 mV.

l. Connect + microvoltmeter lead to TP2. Adjust R53 clockwise for a microvoltmeter reading of zero ± 5 μV.

m. Remove microvoltmeter leads. Connect the 5 1/2 digit test DVM (positive lead) to TP2 on the Attenuator/Reference board, and the negative lead to Gnd pin on Motherboard. Set test DVM to 10 VDC range.

n. Apply −1.0000 VDC to EXT REF terminals and note test DVM reading (approximately +10 VDC).

o. Apply +1.0000 VDC and adjust R55 to obtain the same reading as in step N. Repeat steps N and O until the two readings are within 10 digits (.01%) of each other.

p. Apply −0.1000 VDC to EXT REF terminals directly from DC Calibrator (do not use an attenuator) and note test DVM reading (approximately +1 VDC on 10 VDC range).

q. Apply +0.1000 VDC to EXT REF terminals and adjust R62 until the reading agrees with ± 5 digits of step P.

r. Remove the DC Calibrator from the EXT REF terminals and connect the AC Calibrator.

s. Select capacitive coupled AC EXT REF (SHIFT, HDW, AC) and the 1V external reference range (see step E).

t. Apply 100 mVAC, 500 Hz to EXT REF and adjust R73 for a reading of 1.0000 VDC on the test DVM.

NOTE

The test DVM remains on the 10 VDC range during all these steps.

u. Set AC calibrator to 1 VAC, 500 Hz and adjust R45 for a reading of 10.0000 VDC on the test DVM. Repeat steps t and u until all readings are optimized. optimized.

v. Calibrate the 1000V and 1V Reference Ranges according to the following table.

Ext. Ref. Range	Ext. Ref. Input	Ref. RMS Converter Adjustment	Test DVM Reading
1000V	500 VAC, 500 Hz	R67	5.0000 VDC
1000V	500 VAC, 30 KHz	C27	5.0000 VDC
1V	1 VAC, 40 KHz	C28	10.0000 VDC

w. Perform steps x and y only if major repairs were performed on the Reference RMS Converter.

x. Apply a 1.0V RMS pulse train with a 7:1 crest factor and adjust R52 for a reading of 10.0000 VDC ± 10 digits on the test DVM.

y. Repeat steps t and u on the 1V Reference Range until all readings are optimized.

z. Calibrate 1, 10 and 100V Reference Ranges according to the following table.

Ext. Ref. Range	Ext. Ref. Input	Ref. RMS Converter Adjustment	Test DVM Reading
10V	10 VAC, 500 Hz	R65	10.0000 VDC
100V	100 VAC, 500 Hz	R64	10.0000 VDC
1V	1 VAC, 40 KHz	C28	10.0000 VDC
10V	10 VAC, 40 KHz	C24	10.0000 VDC
100V	100 VAC, 40 KHz	C23	10.0000 VDC

3.8.5.7 SAMPLE AND HOLD FAST A/D (OPTION 03SH).

a. Press ☐ #DIGITS ☐ 3 on the 6000 keyboard to produce internal trigger pulses.

b. Command the 6000, as follows, to read analog voltages applied to the Sample and Hold Fast A/D output connector:

1. If the DMM is connected to a GPIB controller, send the GPIB command G1.

2. If the DMM is not connected to a GPIB controller, short pin 16 and pin 19 of the Sample and Hold Fast A/D connector.

c. Perform the calibration procedures shown below. The input voltages are applied between pin 24 (use as voltage input common) and pin 25 of the Sample and Hold Fast A/D connector.

Voltage In	6000 Readout	Instruction
−10.240 ± .005	−2000	Adjust R26 & R24 together to get −2000 on readout.
+10.230 ± .005	2000	Adjust R26 & R24 together to get 2000 on readout.
Repeat steps (a) and (b) until readout agrees with voltage in.		
−5.120 ± .005	−1000	Check ± 1/2 count error (± 5mV)
5.110 ± .005	1000	Check ± 1/2 count error (± 5mV)

3.8.6 Internal Reference Adjustments.

NOTE

These adjustments are necessary only for instruments containing 4-Wire Ratio Option 34 or AC Ratio Option 11.

CAUTION

Adjustment of internal reference voltages per paragraph 3.8.6 will invalidate any previous calibration of the instrument. These adjustments, if needed, must be performed prior to other calibrations.

3.8.6.1 Remove Calibration Module cover and install AC Ratio/4-Wire DC Ratio bypass card (410764) in J305 and J306. This bypass card is dual-purpose with bypass connections for J305 on one end and J306 at the opposite end.

3.8.6.2 Install calibration cover on Calibration Module, apply power and allow at least one hour warmup.

3.8.6.3 Select DC External Reference (SHIFT, HDW, DC) and 10V range on keyboard.

3.8.6.4 Connect a DC Voltage Calibrator to the EXT REF terminals. Connect the 5 1/2 digit test DVM (positive lead) to TP2 on Attenuator/Reference board, and the negative lead to Gnd pin (Mecca) on Motherboard (near Non-Volatile Memory PCB bracket.)

3.8.6.5 Apply +1.00000 VDC to the EXT REF terminals. Adjust R5 on 10V Reference Assembly for 1.00000V ± 20 μV. Move the test DVM positive lead from TP2 to TP5. Adjust R30 on Attenuator/Reference board for −1.00000 ± 20 μV on test DVM.

3.8.6.6 Select DC Function on Keyboard (take out of external reference mode). Move positive lead of test DVM from TP5 to TP2 and note the test DVM reading (approximately +10 VDC). Move the positive lead of test DVM from TP2 to TP5 and adjust R32 for the same numeric reading (disregard the polarity sign) as TP2 (± 500μV).

3.8.6.7 Repeat the procedures in paragraphs 3.8.6.5 and 3.8.6.6 as needed.

3.8.6.8 Select DC External Reference (SHIFT, HDW, DC) on Keyboard. Increase the EXT REF input to +10.0000 VDC. Note the test DVM reading at TP5 (approximately −10 VDC). Move the positive lead of the test DVM to TP2 and note the test DVM reading (approximately +10 VDC).

3.8.6.9 Select DC Function on Keyboard (take out of external reference mode). With the test DVM positive lead on TP2, adjust R4 on the 10V Reference Assembly for the same reading as TP2 in step 3.8.6.8 (± 100μV).

3.8.6.10 Move the positive lead of the test DVM to TP5 and adjust R32 for the same reading as TP5 in step 3.8.6.8 (± 100μV).

3.8.6.11 Repeat the procedures in paragraphs 3.8.6.5, 3.8.6.8, 3.8.6.9 and 3.8.6.10 as needed.

3.8.7 Repair Adjustment

3.8.7.1 GENERAL.

3.8.7.1.1 After replacing or repairing the Isolator, Ohms or Preamplifier assemblies, the input offset voltage of the Isolator and Ohms Amplifier or the Preamplifier input bias current may need readjustment. These boards are located inside the guard shield enclosure on the Motherboard. The following tests and adjustments are performed with the top cover removed from the guard shield enclosure.

3.8.7.2 ISOLATOR ASSEMBLY (401605).

a. Allow the 6000 to warmup for at least 30 minutes with the guard shield cover and instrument top cover removed.

b. Connect the 5 1/2 digit test DVM to the ANALOG OUTPUT connector on the rear of the 6000. Set the test DVM to the 10 VDC range.

c. Select a 5 1/2 digit Auto-Cal (# DIG, 5). When the Auto-Cal routine reaches DC CAL 7, press and hold the SHIFT Key to prevent the routine from advancing. While holding the SHIFT Key depressed, adjust R34 on the Isolator board for a reading of zero ± 10 digits (± 1 mV) on the test DVM.

d. Release the SHIFT Key and allow resumption of the Auto-Cal steps.

3.8.7.3 OHMS ASSEMBLY (401616).

a. Repeat steps a and b of 3.8.7.2.

b. Select a 5 1/2 digit Auto-Cal (# DIG, 5). When the Auto-Cal routine reaches OH CAL 3, press and hold the SHIFT Key to prevent the routine from advancing. While holding the SHIFT Key depressed, adjust R16 on the Ohms Card for a reading of zero ± 1 digit (± 100 μV) on the test DVM.

c. Release the SHIFT Key and allow resumption of the Auto-Cal steps.

3.8.7.4 PREAMPLIFIER ASSEMBLY (401616).

a. Repeat steps a and b of 3.8.7.2.

b. Select DC Function, 10 mV Range.

c. Alternately switch a short circuit and a 100 KΩ resistor across the INPUT terminals. Adjust R27 until the test DVM changes less than ± 40 digits (± 4 mV).

SECTION 4 APPLICATIONS

4.1 INTRODUCTION.

4.1 This section contains system operating examples for the Model 6000. Each example contains a statement of purpose, a sample program string and the device dependent messages required to program the instrument for the particular application. These examples were prepared using a Hewlett-Packard 9825 calculator connected to the Racal-Dana Model 6000 through the IEEE 488-1975 Standard Interface. Each example contains a program listing as printed by the calculator along with an explanation for each line of the program. If the 6000 is to be used with a Hewlett-Packard Model 9825 calculator, the programming presented in this section may be used directly and/or further modified to suit the users needs. If the programs are used directly, the programmer should check to make sure that the 6000's rear panel address switches are set for an address of "01" (see Section 3.4.5). Because the Model 6000 may be used with any controller which operates on the standard interface bus, the user may wish to prepare equivalent software for another controller device. In such case, the user should review the remote operating instructions to select and assemble appropriate operating statements for the controller to be used.

4.1.2 In the first program sample, line zero of the program is `rem 7` and the accompanying explanation indicates that this statement causes the Hewlett Packard 9825 calculator to send the remote message to all devices on the bus. This statement causes the 6000 to arm for remote operation.

4.1.3 Referring again to the first example, note that line 1 of the program printout contains the statement `flt 6` and that the accompanying explanation indicates that this sets the floating decimal format. This may or may not be a feature or function of the controller in use and, since it is not an interface or device dependent message, use of an equivalent command is at the discretion of the programmer. Line 2 of the program shows the statement `wrt 701`. The explanation indicates that this transmits the device listen address 01. The programmer should select the statement for the controller in use which causes it to transmit the listen address assigned to the 6000. Instructions for the address assignment of the Model 6000 are presented in paragraph 3.4.7. Table 3.11 shows the address switch setting, the talk and listen address characters and the data line binary code for each available decimal address of the instrument.

4.1.4 Line 2 of the first example also contains the program string (composed of the device dependent messages). The examples contained in this section are primarily presented to show the various combinations of device dependent messages required to accomplish the various remotely controlled measurement operations. Note that the program printout indicates the string of device dependent messages presented in the table directly above the program tape. This format is maintained for all of the examples.

4.1.5 Line 3 of the first example is the reply subroutine of the program, and instructs the 6000 to become a talker so it can transmit the measurement data. Line 3 also instructs the calculator to store the transmitted measurement data (in a register known as "Variable A") and to print the data on the program tape. The final line on the program printout is the measurement value –2.001795e01 (–20.0 dB).

> **NOTE**
>
> The Model 6000 will respond to commands written in either upper or lower case letters.

Purpose: Remotely program the AC/AC ratio function and the dB function to measure the attenuation of a 20 dB attenuator.

Program String: F2R4X2Y5L1

Device Dependent Messages:

Device Code	Parameter
F2	AC volts
R4	Range 4 (1 volt)
X2	Software Ratio AC
Y5	Reference Range 5 (10 volts)
L1	Enable dB

```
0: rem 7

1: flt 6

2: wrt 701,"f2r4
  x2y5l1"

3: red 701,A;

  prt A
*6528

    -2.001795e 01
```

Sends remote message to all devices on the bus.

Sets floating decimal (scientific notation) format. Six places to the right of the decimal point, i.e., X.XXXXXXeXX.

Address device 01 (RD6000) as listener and writes a device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Address device 01 (RD6000) as a talker. Reads values into variable A from device 01 (RD6000).

Prints the value stored in variable A.

Answer: –20.0 dB

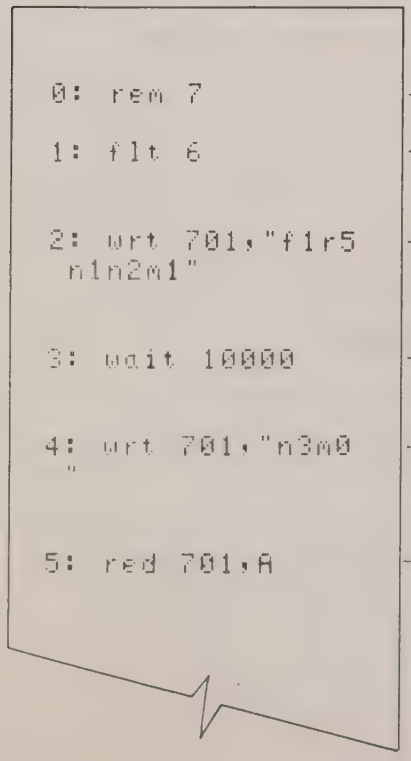
Purpose: Remotely program the DC volts function with the NULL and MAM (minimum-average-maximum) functions to measure voltage variations experienced over a 10 second time period.

Program String: F1R5N1N2M1

N3M0
M2
M3
M4
M5

Device Dependent Messages:

Device Code	Parameter
F1	DC Volts
R5	Range 5 (10 volts)
N1	Enable NULL
N3	Transmit NULL
M0	Disable MAM
M1	Clear and enable MAM
M2	Transmit MIN
M3	Transmit AVG
M4	Transmit MAX
M5	Transmit number of samples



Sends remote message to all devices on the bus.

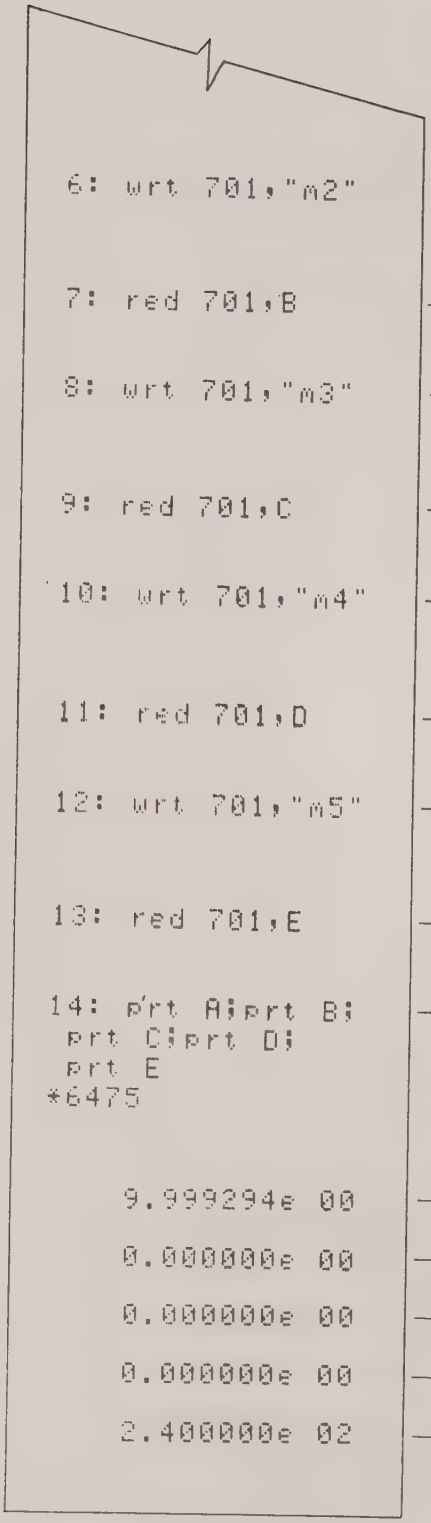
Sets floating decimal (scientific notation) format. Six places to the right of the decimal point, i.e., X.XXXXXXeXX.

Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Tells the controller (HP9825) to wait 10 seconds before executing next instruction.

Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Address device 01 (RD6000) as a talker. Reads value into variable A from device 01 (RD6000).



Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Address device 01 (RD6000) as a talker. Reads value into variable B from device 01 (RD6000).

Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Address device 01 (RD6000) as a talker. Reads value into variable C from device 01 (RD6000).

Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Address device 01 (RD6000) as a talker. Reads value into variable D from device 01 (RD6000).

Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Address device 01 (RD6000) as a talker. Reads value into variable E from device 01 (RD6000).

Prints the values stored in variables A, B, C, D and E.

Answer: 9.9992 NULL

Answer: 0.0000 minimum value

Answer: 0.0000 average value

Answer: 0.0000 maximum value

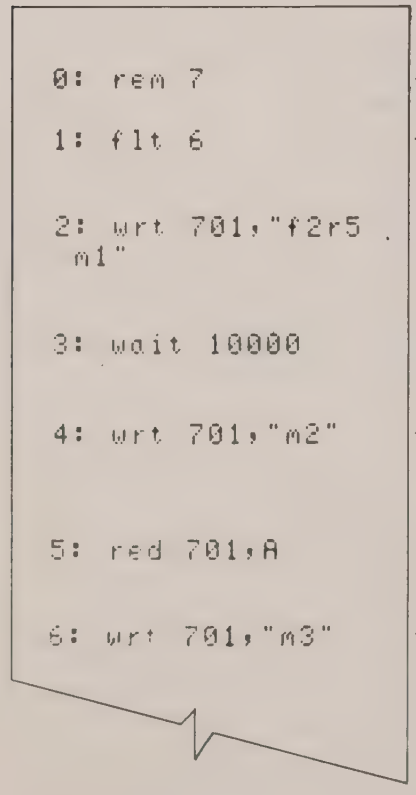
Answer: 240 samples

Purpose: Remotely program the AC volts function with the MAM (minimum-average-maximum) function to measure amplitude variations of a signal source over a 10 second time period.

Program String: F2R5M1
M2
M3
M4
M5

Device Dependent Messages:

Device Code	Parameter
F2	AC volts
R5	Range 5
M1	Clear and enable MAM
M2	Transmit MIN
M3	Transmit AVG
M4	Transmit MAX
M5	Transmit number of samples



0: rem 7 — Sends remote message to all devices on the bus.

1: flt 6 — Sets floating decimal (scientific notation) format. Six places to the right of the decimal point, i.e., X.XXXXXXeXX.

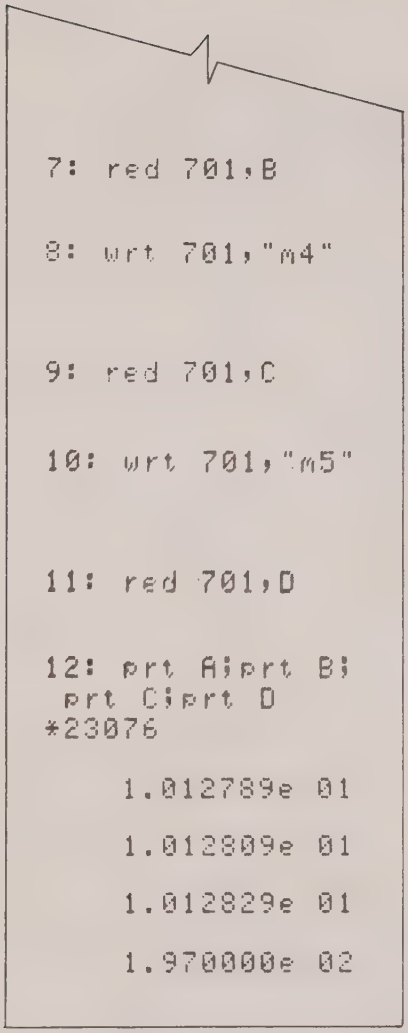
2: wrt 701,"f2r5 m1" — Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

3: wait 10000 — Tells the controller (HP9825) to wait 10 seconds before executing next instruction.

4: wrt 701,"m2" — Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

5: red 701,A — Address device 01 (RD6000) as a talker. Reads value into variable A from device 01 (RD6000).

6: wrt 701,"m3" — Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).



Address device 01 (RD6000) as a talker. Reads value into variable B from device 01 (RD6000).

Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Address device 01 (RD6000) as a talker. Reads value into variable C from device 01 (RD6000).

Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Address device 01 (RD6000) as a talker. Reads value into variable D from device 01 (RD6000).

Prints the values stored in variables A, B, C and D.

Answer: 10.1278 minimum value

Answer: 10.1280 average value

Answer: 10.1282 maximum value

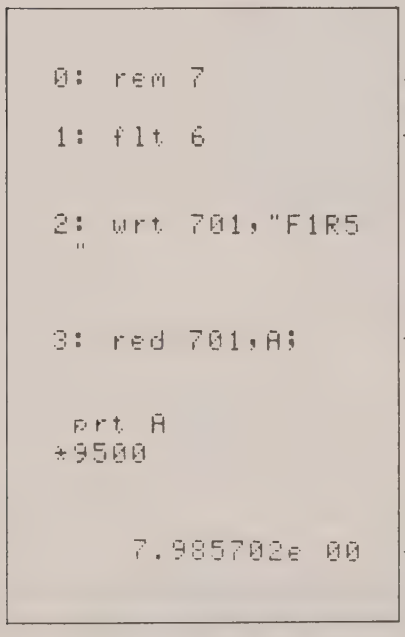
Answer: 197 samples

Purpose: Remotely program the DC volts function to measure 7.9857 volts.

Program String: F1R5

Device Dependent Messages

Device Code	Parameter
F1	DC Volts
R5	Range 5 (10 volts)



Sends remote message to all devices on the bus.

Sets floating decimal (scientific notation) format. Six places to the right of the decimal point, i.e., X.XXXXXXeXX.

Address device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Address device 01 (RD6000) as a talker. Reads value into variable A from device 01 (RD6000).

Prints the value stored in variable A.

Answer: 7.9857 volts

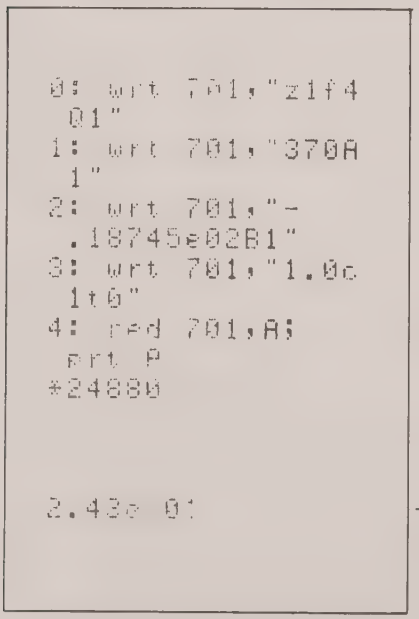
Purpose: Remotely program the 6000 to offset and scale a thermistor output into degrees celsius.

After studying manufacturer's data sheets it was determined that an offset of 370 ohms and a scale factor of −18.745 needed to be applied to the thermistor resistance reading in order to read directly in degrees.

Program String: Z1F4Q1
370 A1
−.18745e02B1
1.0 C1 T0

Device Dependent Messages:

Device Code	Parameter
Z1	Selects: DC, Autorange, internal reference, 'hold' mode, front panel display Disables: filter, NULL, HLL, dB, MAM, (X-A)B/C
F4	Selects ohms
Q1	Enables offset and scaling: (X-A)B/C
A1	Stores the present contents of the input buffer (370) into memory location 'A'
B1	Stores the present contents of the input buffer (−.18745e02) into memory location 'B'
C1	Stores the present contents of the input buffer (1.0) into memory location 'C'
T0	Triggers a single reading



Addresses device 01 (RD6000) as listener and writes device-dependent message followed by a carriage return (CR) and line feed (LF) to device 01 (RD6000).

Addresses device 01 (RD6000) as a talker. Reads value into variable A from device 01 (RD6000).

Answer: 24.3 degrees celsius.

Purpose: During an automated test, a potentiometer on the UUT requires adjustment to reduce an offset voltage to less than ± 2 millivolts. To reduce the adjustment time, remotely program the HLL (high-low-limit) function. Program execution will stop until the potentiometer adjustment is completed.

Program String: Z1T1H9H1
−.002H2
2E-3H3

Device Dependent Messages:

Device Code	Parameter
Z1	Selects: DC, Autorange, internal reference, 'hold' mode, front panel display Disables: filter, NULL, HLL, dB, MAM, (X-A)B/C
T1	Selects internal trigger (continuous readings)
H9	Sets all six HLL limits to initial value
H1	Enables HLL function
H2	Stores contents of the input buffer (−.002) to be used as HLL limit 1.
H3	Stores contents of the input buffer (2E-3) to be used as HLL limit 2.

```
0: wrt 701,"z1T1
 h9H1"
1: wrt 701,"-
 .002h2"
2: wrt 701,"2E-
 3h3"
3: ent "set R34
 for .A. display
  on 6000",2
*24649
```

Addresses device 01 (RD6000) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 01 (RD6000).

Causes the message in quotes to be displayed by the calculator while waiting for the technician to press the calculator's 'continue' button.

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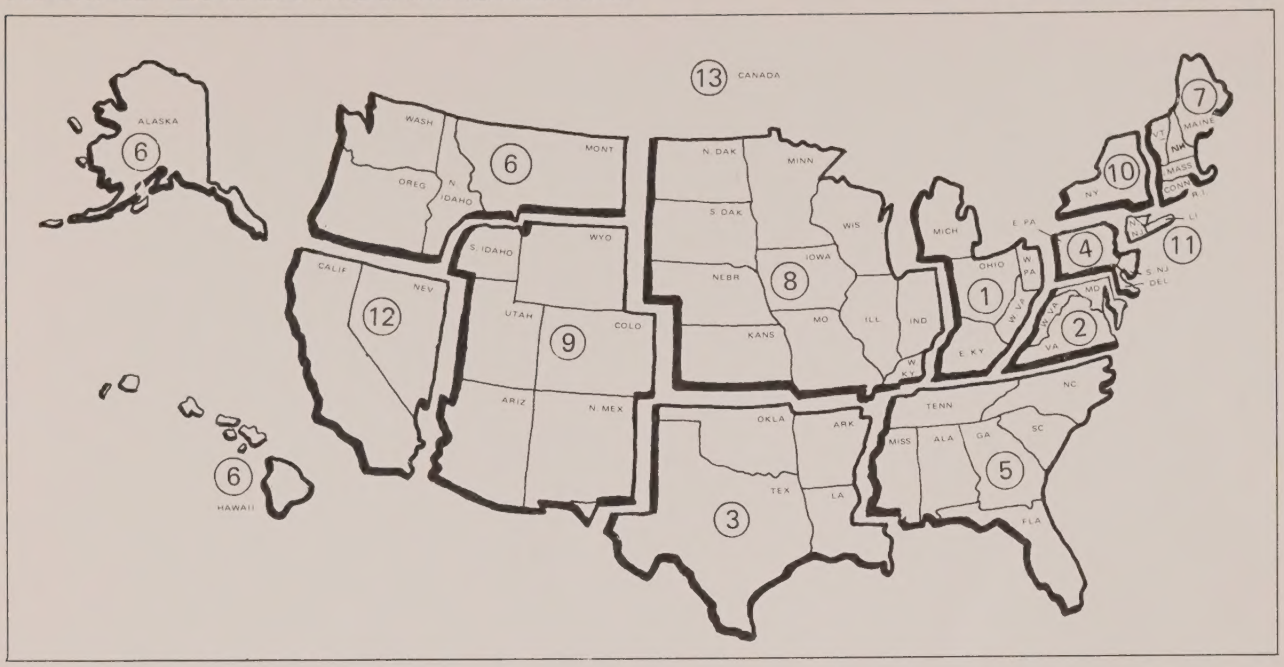

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